The Engineer

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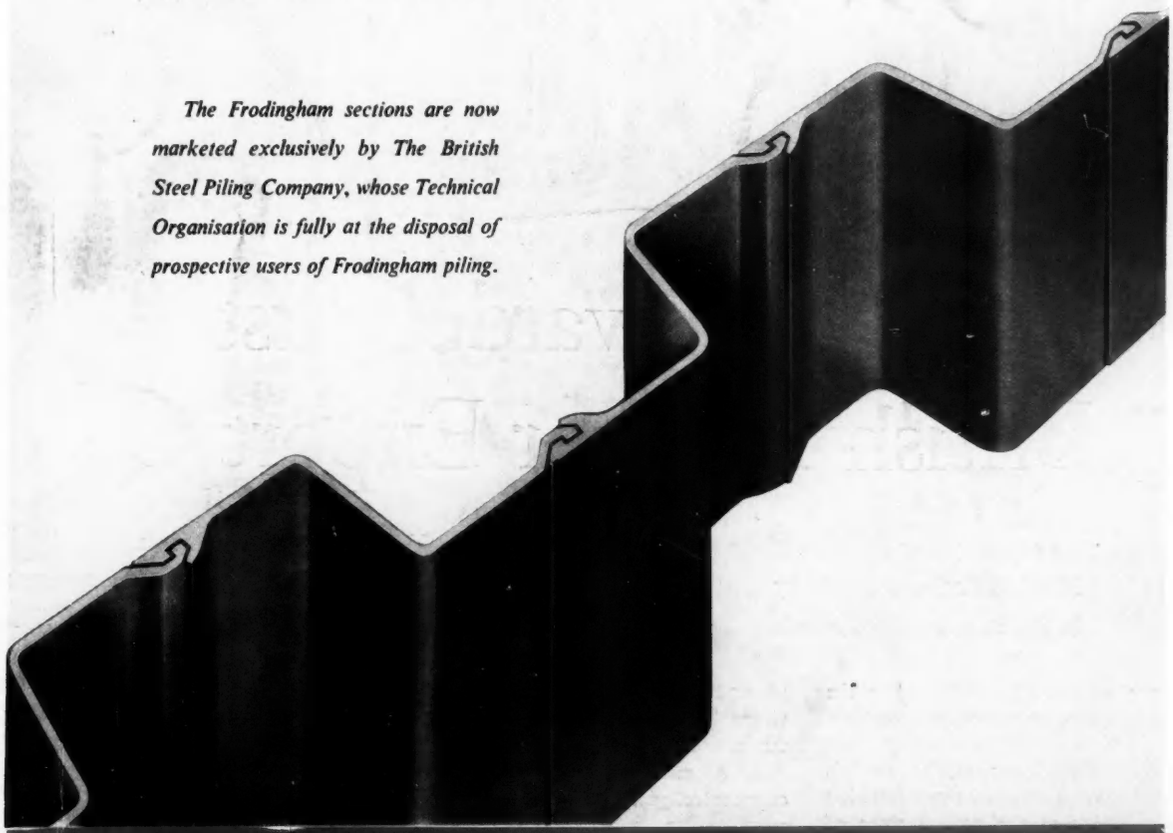

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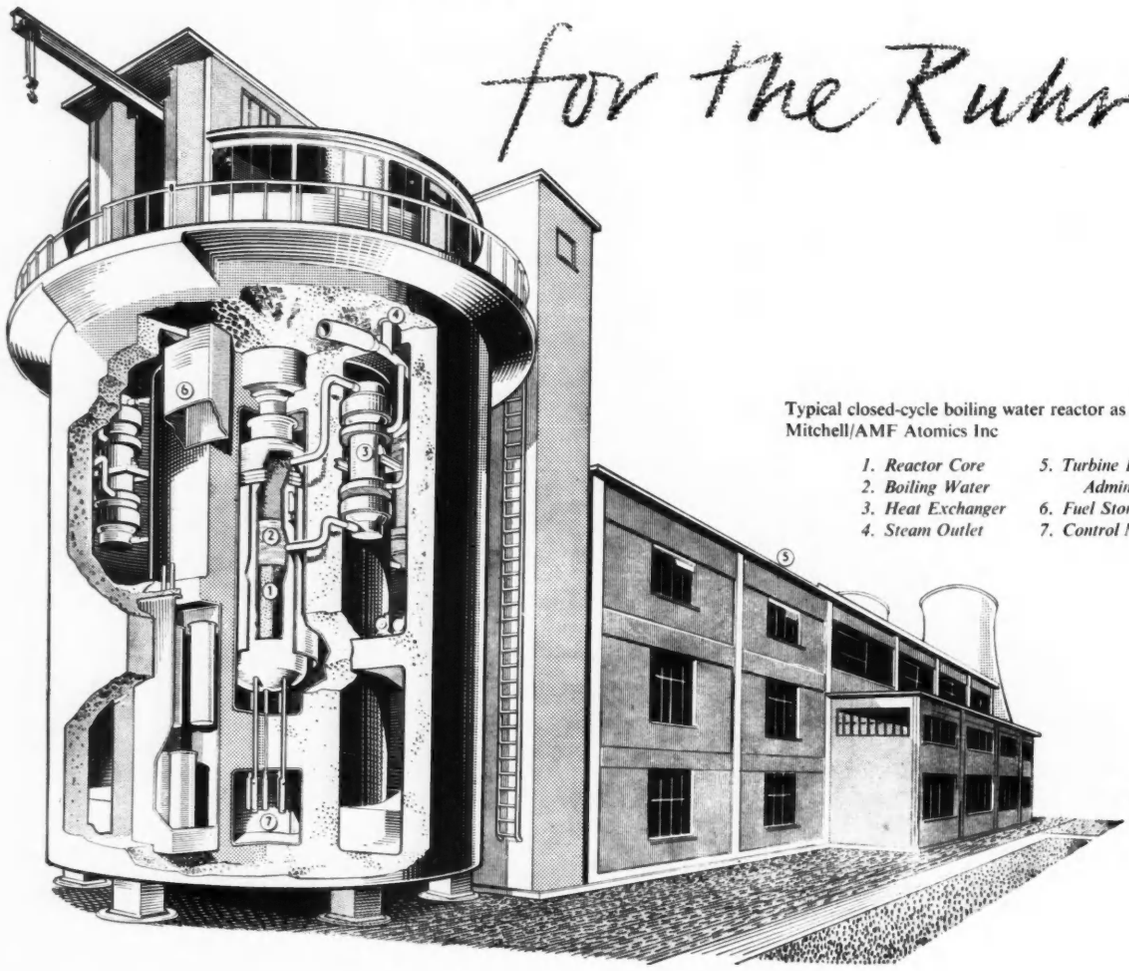
ATOMIC POWER FOR PEACEFUL USE

Atomic Power Station for the Ruhr



Typical closed-cycle boiling water reactor as developed by Mitchell/AMF Atomics Inc

1. *Reactor Core*
2. *Boiling Water*
3. *Heat Exchanger*
4. *Steam Outlet*
5. *Turbine House and Administration Bloc*
6. *Fuel Storage Tank*
7. *Control Mechanism Ba*

Mitchell's awarded first British Reactor Export Order

An atomic power station with an electrical output of 15,000 kW has been ordered from Mitchell Engineering Ltd by Rheinisch-Westfalisches Elektrizitatswerk AG. Mitchells are co-operating in this important export enterprise with their American associates, AMF Atomics Inc of New York.

THE STATION, which will be situated in the Ruhr, is of the closed-cycle boiling water type. The contract was secured in face of competition from seven international companies because this type of reactor was considered the most promising and suitable design at the present stage of development for the capacity required.

Mitchell's share of the contract is valued at over 3 million dollars.

The station is expected to provide electrical power to the grid by 1959. Mitchells are providing the primary and secondary steam circuits, the reactor vessel and heat exchange pipes. AMF Atomics will be responsible for the core, core control gear and instrumentation.

This reactor for the Federal Republic will provide the first practical contribution to the introduction of nuclear power in Germany and is also the first large scale reactor contract to be obtained for export by a British Company. It is a tangible expression of the joint Mitchell/AMF programm for the peaceful development of atomic power. The reactor will be situated below ground.

Mitchells are also engaged on a total of fou contracts for British Atomic Plant at Chape cross, Capenhurst, Springfields and Dounrea

MITCHELL

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THE ENGINEER

VOL. 203 No. 5283 APRIL 26, 1957

CONTENTS

LEADING ARTICLES—
The Role of the Drawing Office 629
The Customer and the Strikes 630

ARTICLES—
Australian Copper Industry 658
Automatic Control for Oil-Fired Boilers. (Illus.) 655
British Conference on Automation and Computation 631
British Non-Ferrous Metals Research Association 638
Changes in a 50m Mural Tape Standardising Base. (Illus.)... 632
Civil Engineering in Heavy Industry. (Illus.) 650
Compression Testing Machines for Concrete. (Illus.)... 639
Distribution Method for Circular Cylindrical Shells. (Illus.) 634
Fluid Bed Technique for the Textile Industry. (Illus.) 651
Fork Lift Truck. (Illus.) 656
Helium Drier and Adsorber for "Dido" Research Reactor. (Illus.) 654
High-Temperature Vacuum Furnace. (Illus.) 655
Inclinometers for Use in Long Underground Boreholes. (Illus.) 655
Institution of Naval Architects. No. IV 644
Joint for Polythene Tubes 653
Lloyd's Shipbuilding Returns 634
Nomogram for Steam Condenser Design. (Illus.) 642
Park Lane Improvement Scheme... ... 631
Pollution in the Thames Estuary 631
Rotary Drill. (Illus.) 656
Soil Stabilisation at Southend Airport... 631
Spares Storage and Handling. (Illus.)... 653
Transmission Gear Heat-Treatment Installation. (Illus.) 652
5MeV Linear Accelerator for Industrial Radiography. (Illus.) 654
100 Years Ago... 630

METALLURGICAL TOPICS 646

CONTINENTAL SECTION—
European Atomic Community 659
Tube-Straightening Machine. (Illus.) ... 660
Electric Cable for Remote Control ... 660

AMERICAN SECTION—
Experimental Boiling Water Reactor at the Argonne National Laboratory. No. II. (Illus.) 661

LETTERS AND LITERATURE 648

LETTERS TO THE EDITOR—
High-Voltage Surge Generators ... 648
Laminar Free Convection : A New Formula 648
Let's Forget the Cycloid Tooth ... 648
Hydro-Pneumatic Engine 648

BOOK REVIEWS 648

NEWS AND NOTES—
Advanced Engineering Courses 666
British Patent Specifications. (Illus.) ... 665
British Standards Institution... 649
Catalogues and Brochures 666
Forthcoming Engagements 666
Industrial and Labour Notes... 657
Launches and Trial Trips 666
Personal and Business 664

THE ROLE OF THE DRAWING OFFICE

Of all items in the engineer's stock-in-trade none has varied so widely in the past, from establishment to establishment, from job to job, as that vaguely-defined, often-abused, yet sacrosanct document, the drawing. Whereas a lathe, for example, whether large or small, simple or complicated, cannot be anything but an instrument of precision, drawings used for production have varied from free-hand thumbnail sketches, to dossiers containing a hundred or more elaborately drawn details. In days gone by the designer was often the manager himself, or even the owner, and a sketch made with a stick in sand on the foundry floor was enough to get an article into production : no planning, no progress work, no paper work. Again prototypes of new machines were often made to the roughest of sketches, and development work was carried out by craftsmen. The drawing, when it came to be made, was a record of what had been established in the shop. Even where drawings of a more comprehensive kind were issued much was left to the "know-how" of the foreman in the works, and many a senior designer of to-day, racing against time, and having to settle detail down to the last "thou" must occasionally think back wistfully to his younger days when he could, for example, specify a "push fit," and leave it at that. He could rest assured that the shops would know what to do. To-day, however, the whole pattern of engineering production has changed. Many circumstances have arisen to make the association between drawing office and shops much less intimate, if not necessarily remote ; the result is that the engineering drawing of to-day has become a much more precise document in its details of material, processing, and dimensioning.

The third edition of the *Drawing Office Handbook*, which is reviewed elsewhere in this issue, refers to some of the factors that have accelerated this change. In many branches of the industry it had begun in the years between the two wars, but it was above all the vast amount of sub-contract work involved in the armament programmes of the second world war that made it necessary for drawings to carry every scrap of information needed for manufacture. The parent design office might be a hundred miles or more from the works ; liaison in the old style would be impossible, and where firms were undertaking work entirely new to them "know-how" on the shop floor was nil, absolutely nil ! Gradually a new conception of drawing office responsibility was formed. It was a conception to be appreciated from both sides. Formerly, many a works engineer finding some impracticable detail on a drawing had made his own adjustments, and not considered it necessary to tell the drawing office. An amended "shop practice" would be in force, and so long as there were older hands to pass on the practice to the younger men all would be well. But in present circumstances managerial policy might decide that this very item is to be sub-contracted. We know of many such cases, some where the sub-contracting, or manufacture under licence, was on the opposite side of the Atlantic, in which the "shop practice" was not passed on, and difficulties in manufacture resulted. To-day there can be no such loopholes. The information on the drawing must be complete, and kept constantly up to date with any changes in practice or manufacturing technique found necessary in production. In consequence the role of the drawing office is more extensive than ever before.

In an establishment of any size even the more experienced of designers could not hope to have so precise a knowledge of shop capacity as to specify with certainty the exact details of manufacture. Consultation is necessary, and the more elaborate the machine the wider must the sphere of consultation be extended. To-day, however, so many firms are in process of rapid expansion that men relatively fresh to the job, albeit holding high technical qualifications, are called upon to take responsibility for design, and in such cases the need for consultation is doubly necessary. Quite apart from any consideration of the sales angle the time necessary to get a new design into shape for efficient production is considerable before the detailing of the components can be started. The very comprehensive nature of the information needed on the detail drawings, and the need for meticulous cross-checking after completion is reflected in the rapid increase in drawing office staffs in recent years. Even in the detailing stage close liaison with works interests must be maintained. Problems in connection with the ordering of material, shop organisation and work study are likely to arise, and these in turn may lead to reconsideration of certain details in the drawing office. To-day the designer has always to keep prominently in mind the question of whether a material he specifies is liable to be scarce. While in former days the designer's, or draughtsman's, contact in the works might well be the shop foreman, a charge-hand

erector, or leading fitter, each of whom by longevity of service had become something of an oracle, to-day the works contacts are more likely to be the planning engineers, the work study men, and the purchasing section. Only by such continuous contact can the information presented on drawings be complete, and enable a factory to work to it without any overt or covert variations to assist production.

THE CUSTOMER AND THE STRIKES

In connection with the strikes which lately threatened grave damage to the national industry of Great Britain, one aspect seems to have been rather lost sight of: the feelings and reactions of overseas customers upon whose interests severe injury would certainly have been inflicted. Since full and remunerative employment is dependent, in the long run, upon a sufficiency of customers, it must be self-evident that if manufacturing industry is to collapse when faced with an issue soluble by deliberation, the resentment of customers will be among the baleful consequences. Surely this is an aspect to be carefully weighed by the executives of trade unions and its significance made known to the men whose interests it is their business to protect. Moreover, there ought to be a department of the Trades Union Congress charged with the task of assessing the injury caused to the export trade by industrial disputes and the threat of such. It would be the duty of this department to study, among other things, evidence disclosed by cables and correspondence from overseas buyers whose requirements are threatened and who—at their own expense—are obliged to take such action as will diminish frustration and loss to themselves. In the case of the dock strikes which took place not long since, serious hardship was experienced beyond the immediate perimeter of the dispute and it fell upon workmen other than the dockers in the shape of lost and cancelled orders. Severe, indeed, is the damage caused due to anxiety on the part of overseas buyers with regard both to the delivery and ultimate cost of orders placed in this country. The effect of these recurring shocks is inescapable and were the facts understood by all participants in industry, something effective would be done about it. A year or two back the general secretary of the Shipconstructors' and Shipwrights' Association did something effective by mentioning, in his annual report, that requests had been received from some districts asking that the Government be approached to place a ban on British shipowners taking their repairs abroad. The comment by the general secretary was—as reported in the newspapers—that:

"Ships of every nation trade to British ports and a considerable amount of that shipping undergoes repairs which in volume is far more than that which is taken abroad from the United Kingdom for repairs. Consequently, we should be very loath to place a ban on British ships being repaired abroad and thereby invite retaliatory measures which would, in the long run, prove detrimental to the interests of our own ship-repair workers. The answer to the problem must be good quality workmanship and expeditious service."

It seems truly deplorable that at a time when the order books of the nation—and particularly of the shipyards and marine engineering works—are well filled, the sky should be darkened by threats of stoppages which, were the circumstances better understood, could never be brought about. What sense is there in expecting future harvests if the fields can be wantonly abandoned? The persistence of such tragic absurdities appears to be largely due to procedures, the effect of which is to create not harmony but havoc; to attempting to kick the door down when what is needed is a key to open it. It is high time that the machinery which results in such havoc should be repaired or replaced by something which will work without recurring breakdown. Now that we are in possession of all manner of new and epoch-making tools, must we continue to impoverish ourselves by horse-and-buggy methods in respect of labour relations? Not long since, Dr. Vannevar Bush remarked that "an informed and intelligent electorate is our bulwark against political chaos." Against industrial chaos the best bulwark should be found in an intelligent aggregate of men intent on seeing that their interests are in the hands of the wisest and best-informed executives whom it is possible to nominate. One thing imperative is that precautions be taken which will obviate strife and losses due to what is called "face saving," indulgence in which has often to be paid for at great cost by innocent people.

Since the persistence of an export market is dependent on efficient and punctual service as well as on competitive prices, we can ill afford to inflict recurring shocks upon customers and potential customers. While emphasis is rightly placed on the importance of endeavouring to maintain and to improve what are called living standards, how can this ever be possible if we are so foolish as to ignore the dependence of living standards upon output? This is something which only we ourselves can attend to and it is high time that everyone connected with industry should realise that to talk about raising the standard of living while at the same time persisting in the use of such an anachronism as the "strike" weapon is sheer madness. Someone has remarked that we live in "an era of technological complexity, advancement and radical changes." It is very true and surely in such an era the creative and productive work of the nation requires a climate in which it may be permitted to thrive. Certainly the word "strike" has become entirely obsolete as applied to industrial disputes, the thing intended being damaging—directly or indirectly—to all concerned. We may remember how on an occasion when his secretary told him that what he had asked for was impossible, the illustrious Mirabeau, starting up from his chair, exclaimed: "*Impossible! Ne me dites jamais ce bete de mot!*" ("Never name to me that blockhead of a word!") Surely "strike" has become a blockhead of a word in days when our future existence as an industrial nation must depend upon immunity from industrial warfare. Deliberation, patience and the avoidance of inflammatory talk are essential in the maintenance of industrial harmony and we need them desperately. Deliberation and patience will always be found sovereign in their influence upon those who understand the facts, and we may take encouragement from the words of that wise man and great labour leader, the late Mr. Ernest Bevin, who, speaking in the House of Commons just twelve years ago, remarked "There has never been a war yet which, if the facts had been put calmly before the ordinary folk, could not have been prevented."

The Engineer
100 Years Ago
(APRIL 24, 1857)

"How's Ship Pump and Fire Engine"

"We had an opportunity of witnessing on Wednesday last the operation of one of the most compact and ship-shape arrangements in the way of a ship's pump that we ever remember to have seen. The pumps, two in number, as arranged by Mr. How, are double acting, and occupy little more room than a single acting pump of the ordinary construction. The valves are simple and very easily got at, which is a point of much importance, especially in ship's pumps. The faces of the valves are fitted with india-rubber rings, so that any noise or hard beating of the valves is entirely avoided. There are four different suction orifices, so that the pumps can be made to draw from several parts of the ship at the same time, and there are valves which can be screwed down so as to close two of them at pleasure. The barrels of the pumps, the valves, as well as the framing for supporting the working lever, are all placed upon a small base plate, which can be bolted at once on to a deck of a vessel, or can be put upon a wooden framework upon wheels so as to constitute a good and efficient fire engine. . . .

"We are always glad to call attention to useful arrangements of machinery, especially where the inventors or makers do not guarantee to do the same work as with other arrangements with half the power. The merits claimed for the invention under notice are simplicity of arrangement and convenience, and these merits it possesses, and we trust shipowners and shipbuilders will take an opportunity of examining it for themselves before sending vessels to sea with the old fashioned pumps which seem so given to choking."

A Seven Day Journal

Park Lane Improvement Scheme

THE Minister of Transport and Civil Aviation, Mr. Watkinson, has announced that an improvement scheme for Park Lane has been approved in principle by the Government with the addition of an underpass linking Piccadilly and Knightsbridge. The scheme is being prepared by the L.C.C. and will cost some £3,000,000. It provides for the complete reorganisation of the road system on the eastern side of Hyde Park and alterations at both Hyde Park Corner, which, the Ministry points out, is the busiest road junction in London, and at Marble Arch, which is the third busiest. The Ministry adds, furthermore, that the scheme will have the effect of relieving congestion in Oxford Street, Piccadilly, Knightsbridge and other main streets in London, and in the Minister's opinion it is the heart of the Inner London traffic problem. Park Lane is to be used for southbound traffic only and a second carriageway will be built for northbound vehicles near the line of the East Carriage Road of the Ring in Hyde Park. A tree-lined grass reservation will separate the two carriageways and thus form "a fine boulevard suited to modern traffic requirements."

There will be a substantial enlargement of the roundabout at Hyde Park Corner, and the introduction of an additional roundabout to the immediate north. The Decimus Burton Screen, which now forms an entrance to Hyde Park, will be retained, but the gateways will not be used by vehicles except for ceremonial purposes; similarly the road through the main island to Constitution Hill will be retained for processional use. The roundabout system at Marble Arch will be considerably modified and arrangements will be made for access to and from Mayfair to the boulevard at Grosvenor Gate and Stanhope Gate.

The Government has now decided in favour of the scheme outlined above, which has been under review since 1948, subject to consideration of any views which the London and Home Counties Traffic Advisory Committee and the Royal Fine Art Commission may wish to put forward. Parliamentary powers will be required before it is built. Since 1954 there has been an increase of 12 per cent in the number of vehicles using Hyde Park Corner each day.

Pollution in the Thames Estuary

THE D.S.I.R.'s report for the year 1956, *Water Pollution Research*, has just been published. It is pointed out that a concentration of effort, with the resources available, has been followed consistently for some years, to give thorough investigation of selected aspects of the problem of pollution. For instance, a large proportion of the work concerns the survey of the Thames estuary. The success of this investigation now seems assured, it is stated. It has been found possible to assess quantitatively the various factors which determine the distribution of oxygen in solution in the estuary—a distribution on which the presence or absence of nuisance at any time depends. The observed distribution of oxygen under present-day conditions is very similar to that predicted from a knowledge of the polluting matter entering the estuary, the rate at which it is oxidised, the rate of re-aeration from various sources, and the movement of the estuarine water under the influence of tidal and fresh water flow. It is therefore possible to predict by the same methods what the approximate effect will be of making changes in factors which affect the distribution of oxygen. For example, the contribution made by each of the major discharges of polluting matter to the estuary in bringing about the observed deficiency of oxygen can be assessed, as can also the effect which would be produced if a new discharge were made at any given position.

It is now clear, the report points out, that one reason why it is possible to calculate what will be the effects in the Thames of a given polluting load is that the estuary is a large and deep body of water in which changes due to fluctuations of weather or pollution occur relatively slowly. It may well be more difficult to make similar predictions about the effects of polluting discharges on fresh water rivers in which uncontrollable changes—for example, in flow and turbulence—may result in much wider and more frequent fluctuations in oxygen distribution. Nevertheless information on this matter is badly needed if the purifying capacity of a river is to be taken into account in deciding the quality of an effluent which may be discharged to it. It is known from work at the Laboratory that the purifying capacity varies very widely from one stream to another; discharge of a quantity of effluent to a turbulent and shallow stream might cause an insignificant reduction to its oxygen content, but the same proportion in a deep and slow-flowing river might bring about anaerobic conditions and a public nuisance. A beginning has been made in studying the factors which affect purifying capacity, but, it is pointed out, clearly much more work is required.

British Conference on Automation and Computation

BECAUSE of the growth of the new industrial techniques, popularly known as automation, which also comprise computation, process control and data processing generally, and because of the numbers likely to be affected by their application, it has been felt for some time that there is a need for the establishment of some form of liaison between all the interested organisations. There were several independent discussions at the end of last year, each having the object of setting up a suitable organisation, and much useful preparatory work was done in this way.

It was realised, however, that a broadly based structure was desirable, and, at the invitation of the Institution of Civil Engineers, the Institution of Mechanical Engineers and the Institution of Electrical Engineers, exploratory conferences were held on March 6 and April 16, as a result of which the representatives of about twenty organisations, with interests in the fields of automation and computation, approved proposals for closer collaboration, and agreed to recommend them to their councils for adoption. The proposals, if accepted by the bodies concerned, will result in the setting up of a British Conference on Automation and Computation, which will be organised in three groups of societies, having the following fields of interest: the engineering applications of automation techniques; the development and applications of computers, automatic controls and programming techniques; and the sociological and economic aspects of automation and computation procedures. These three groups would be convened, respectively, by the Institution of Mechanical Engineers, the Institution of Electrical Engineers, and the British Institute of Management. An essential factor of the proposals is that liaison between the groups should be established on a permanent basis from the outset, and it is foreseen that the central unit of the Conference which will be established for this purpose will undertake such other duties as may be deputed to it by the groups as, for example, the preparation of periodical digests of published papers falling within the general fields of automation and computation.

If the proposals are approved by the councils of the several societies represented at the exploratory conference, the conveners and sponsors of each group will summon further meetings, to which will be invited representatives of all the bodies which appear to have interests in the particular group, with a view to their membership and collaboration. Any other body would be very welcome to apply for membership of the groups in which it felt its interests lay. At these conferences detailed arrangements will be settled for liaison within the United Kingdom between the various bodies participating in the groups, and between the groups themselves, so that progress in the fields of automation and computation and their applications can be fostered, and so that internationally the British contribution can be focused. All societies and institutions interested in the subject will be most welcome to support the activities of the conference by applying for membership of the appropriate group or groups.

Soil Stabilisation at Southend Airport

LAST week we attended the showing of a film about the construction of runways at Southend municipal airport. This work has been noteworthy for the use of soil cement as the main material of construction for the runways, which are topped with a wearing surface of only 2in of gravel asphalt. A good idea of the general method of construction for this class of work, and of the plant employed, is given by the film. Generally, a depth of stabilised soil of 14in was needed, which was achieved by stabilising in two layers, using the mix-in-place method. In parts of the work, however, three layers of stabilised soil had to be included; soil for the upper layers was handled by large scrapers. The runways were designed for wheel loads of 40,000 lb with tyre pressures of 110 lb per square inch. The high degree of mechanisation and the high rate of progress of the work were stressed. The daily output was between 3000 and 4000 square yards, and the labour force seldom exceeded thirty men, including those on ancillary works, such as drainage.

The film was made by the contractors for the Southend runways, Gough, Cooper and Co., Ltd. The audience consisted of representatives from Government and local government service, research organisations and so forth, and a discussion of various technical aspects of soil stabilisation took place after the film had been shown. Construction of this kind has been fairly widely used in this country for road work, and three recent applications to airfield construction, including the Southend runways, were described in papers presented at the Institution of Civil Engineers last December, and published in the current issue of the Institution's *Proceedings*.

Changes in a 50m Mural Tape Standardising Base*

By L. O. C. JOHNSON

The dimensional stability of the brick structure forming the base of the 50m mural comparator used at the National Physical Laboratory for the standardisation of geodetic and other surveying tapes is discussed. In forty-two years the base has increased in length by 12mm : it is still lengthening at the rate of about 0·2mm per annum. Other changes in configuration have not, in general, exceeded 2mm.

THE dimensional changes which have occurred during forty-odd years in the long mural base used at the National Physical Laboratory in the standardisation of precision measuring tapes will doubtless be of interest not only to those concerned with length measurements for geodetic and surveying purposes, but to civil engineers and others who are concerned with the dimensional stability of brick structures.

This base, which has already been described in THE ENGINEER[1] consists of a bench built in 1908 of mortar-bonded Fletton bricks. It extends for 165ft along the inner side of a 5ft wide corridor situated on the south side of the old Metrology building, Fig. 1. The surface of the bench is 4ft 6in above the floor and the brickwork is integral with a 9in wall 12ft high, separating the tape testing corridor from eight standards rooms. The dividing walls between these rooms thus form buttresses to the bench. Blocks of Portland stone are built into the brickwork at the top of the bench at intervals and they each carry two nickel-steel insets bearing graduation lines, Fig. 3. One inset in each block, in conjunction with corresponding insets in the other blocks, serves in defining intervals along a line about midway across the top of the bench. Similarly, the other inset serves in defining intervals along a line on the edge of the bench. These nickel-steel insets occur at every 4m from zero to 48m with additional insets at 10m, 25m, 50m, 50ft, 66ft, 100ft, 132ft and 150ft (1ft = 0·305m).

Owing to wear, the insets on the edge have recently been regraduated. As a preliminary, their spacing and alignment were remeasured, and it is, therefore, appropriate to place the dimensional history of the bench on record at the present time. It should be understood that in the verification of measuring tapes the bench is used merely as a transfer standard, its length being kept under close observation by frequent recalibration with precision metal line standards and intervening checks with the sag-wires previously described.[1]

* Communication from the National Physical Laboratory.

CHANGES IN LENGTH

Of the two sets of bench marks, only those along the front edge have been measured with sufficient frequency to give an indication of the movements of the bench. A few measurements made earlier than 1913 showed that a secular increase in length was taking place. From 1913 onwards, with the aid of specially graduated standard Invar tapes, the intervals between the various bench marks on the edge of the bench have been standardised from time to time. Throughout the period 1913 to 1952 the temperature of the brickwork was assumed to be that given by mercury-in-glass thermometers placed on or near the bench. The temperatures obtained in this way were used in computing the length of the bench at 20 deg. Cent. In 1952 resistance thermometers were provided with their measuring elements embedded in the bench wall[2] and from that time on temperatures given by these thermometers were used in making reductions to 20 deg. Cent. In 1948 an analysis was made of standardisations of the bench covering four periods of its history and from each of these a value was derived for the thermal expansion of the brickwork. The results of this analysis have previously been reported[1] but for convenience are repeated here in Table I. All these values for the thermal expansion

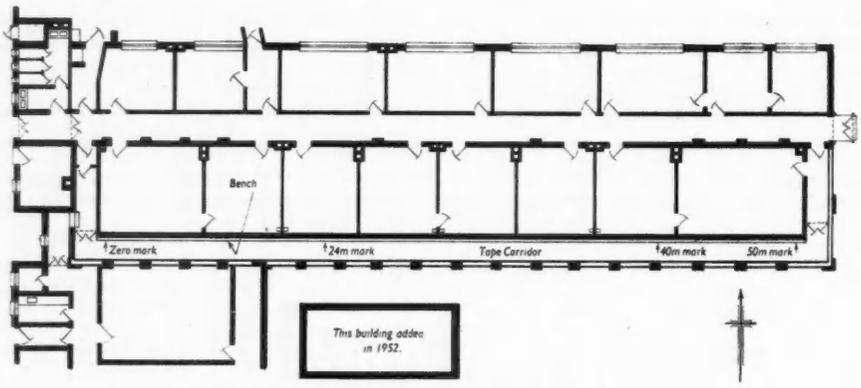


Fig. 1—Plan of metrology building showing the tape corridor

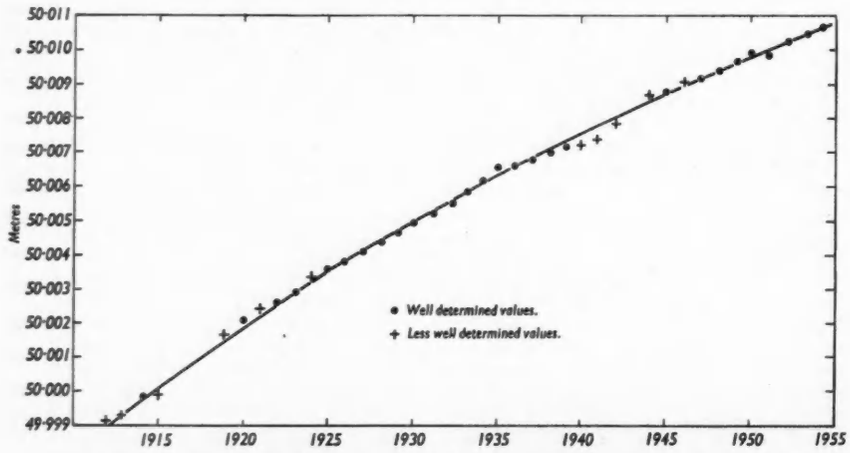


Fig. 2—Yearly mean length at 20 deg. Cent. of interval between bench marks 0m and 50m

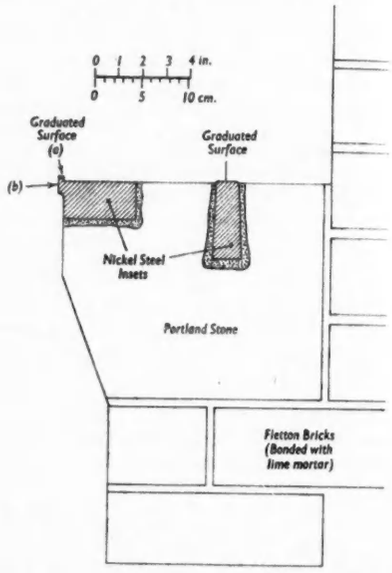


Fig. 3—Cross section through mural base at bench marks

TABLE I

Period	Number of observations	Temperature range, deg. Cent.	Coefficient of expansion per deg. Cent.
1913–15...	19	13·7 to 19·5	$3·18 \times 10^{-6}$
1919–22...	39	13·4 to 23·8	$2·66 \times 10^{-6}$
1923–34...	27	13·5 to 23·1	$2·86 \times 10^{-6}$
1935–40...	13	15·5 to 21·8	$2·64 \times 10^{-6}$
		Weighted mean	$2·8 \times 10^{-6}$

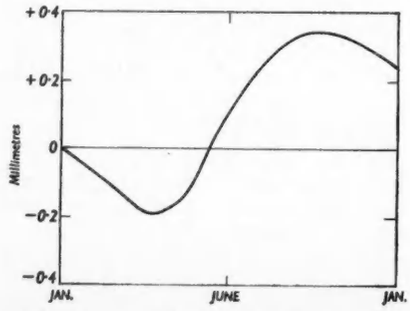
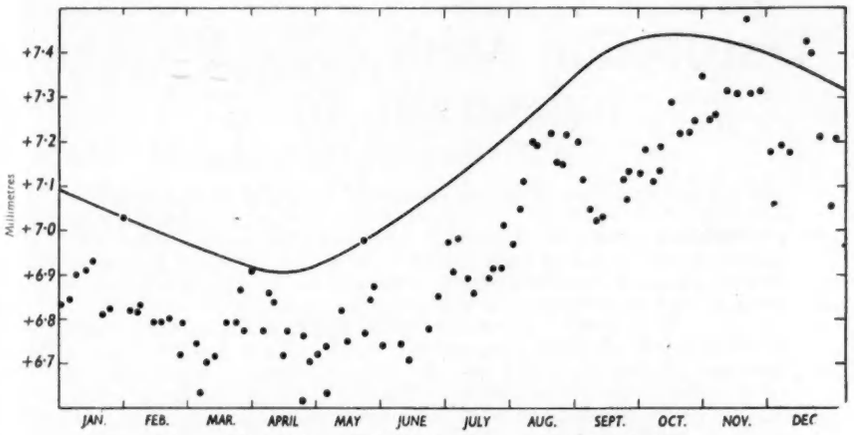


Fig. 4—Mean seasonal fluctuation in length of bench



The curve indicates the lengths in 1938 based on the curves given in Figs. 2 and 4

Fig. 5—Observed lengths in excess of 50m of bench interval 0m to 50m at 20 deg. Cent. during 1938

are lower than the value commonly accepted for clay bricks.

The interval 0m to 50m has been measured many times by means of standard tapes since 1912 and additionally and very frequently since 1922, with the help of the sag-wires. The results of these observations, reduced to 20 deg. Cent. by using the mean value for the thermal expansion given in Table I, are shown graphically in Fig. 2. The individual points indicate the mean measured length of the bench for each year and the curve represents the relationship $l = 50{\cdot}037\ 13 - 3{\cdot}6661/(t + 84{\cdot}13)$, where l is the length at 20 deg. Cent. of the bench in metres at the time t reckoned in years from 1900. In deriving this relationship the less well-determined points have been neglected. The maximum deviation from the curve is within 0·20mm and the standard deviation is 0·11mm. The rate of increase in the overall length of the bench in 1912 was 0·4mm per year. This had dropped to 0·3mm per year by 1930 but in 1954 it was still as large as 0·2mm per year.

Superimposed on the long-term lengthening is a seasonal fluctuation. This is illustrated in Fig. 4, which gives the mean variation for a number of typical years in each of which the observations were evenly distributed throughout the year. The bench, at 20 deg. Cent., actually shortens from September to March and lengthens by a greater amount during the following period April to August, the average annual increase being shown by the difference between the two ends of the curve. It is not easy to assign a reason for these fluctuations ; they may be due to soil temperature, it being significant that the maxima and minima coincide roughly with the highest and lowest yearly soil temperatures. On the other hand, the fluctuations may be due to the water content of the soil.

In order to show the apparent variations in overall length which occur over periods of a few days a typical year has been chosen for analysis, namely 1938. About two observations from each week have been reduced to 20 deg. Cent. and plotted. The results are given in Fig. 5, which also includes a curve calculated from the equation given above with the mean seasonal variation added. Nearly all the observations give a lower value than calculated, the mean difference being about 0·2mm in accordance with Fig. 2. The scatter, which occasionally amounts to ±0·2mm (±0·4 parts in one million) is greater than would have been expected from the errors of the basic length measurements, and therefore must be due, in part at least, to a lack of knowledge of the thermal expansion of the brickwork coupled with the uncertainty of the temperature measurement. It is noticeable in the Laboratory records that observations which show the greatest deviation invariably follow sudden changes in the recorded temperatures. However, this source of error cannot affect the mean length of the bench to any great extent over several weeks or months. In Fig. 2 the deviations of most of the points from the smooth curve are therefore due, in part at least, to real digressions from a regular rate of growth.

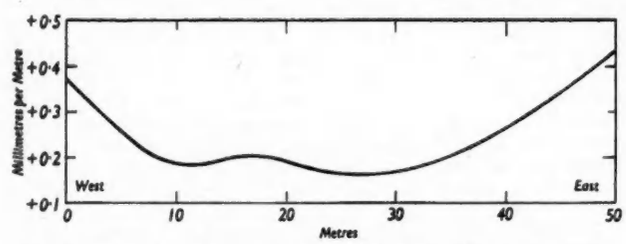


Fig. 6—Local rate of increase in length of bench in millimetres per metre in 40 years

A similar analysis to that made for 1938 was made for all the observations between June, 1952, and June, 1953, when the temperatures recorded were those given by the new resistance thermometers with their measuring heads embedded in the wall and the temperature of the bench corridor was thermostatically maintained at about 20 deg. Cent. During this period the scatter of the results was only slightly less than that during 1938, an indication that either the effective temperature of the wall is still not well enough known despite the use of embedded thermometers, or that the bench is not entirely free to follow changes in temperature.

From time to time all the intermediate intervals along the bench have been standardised and the results give an indication of the uniformity of the increase along its length. For the present purpose it is sufficient to compare measurements made when the bench was comparatively new in 1913 with measurements made in 1953. The mean increase has been 0·23mm per metre over the intervening forty years, but the rate of increase has been more than twice as great at the ends as it has been at the centre. Fig. 6 shows the mean rate of the increase in length at the various parts of the bench. The fact that the increase has been smaller at the west end (zero) than at the east end (50m) may be due to extra constraint imposed by additional rooms adjoining the bench corridor at the west end.

In spite of the large changes in length which have occurred it is noteworthy that the brickwork shows no signs of cracks.

Changes in Level

The levels of the bench marks on the front edge of the bench, (*a*) in Fig. 3, relative to the 24m bench mark have been measured on three occasions, viz. in 1909, 1920 and 1955. It is not known how the 1909 measurements were made, but those of 1920 and 1955 were made by reference to a water surface, 50m long, in a tank mounted on the opposite wall of the corridor for use in the measurement of the thermal expansion of geodetic tapes. The changes in level between 1909 and the subsequent years are shown graphically in Fig. 7. The results show that between the 4m and 48m bench marks there has been a fairly uniform tilt, the west end having sunk relatively to the east end by approximately 2mm. The zero bench mark at the west end has sunk, relatively, by a further 1·5mm while at the east end the 50m mark has risen 0·6mm less than the amount indicated by the general tilt.

Alignment

The alignment of the faces, (*b*) in Fig. 3, has been examined on three occasions, in

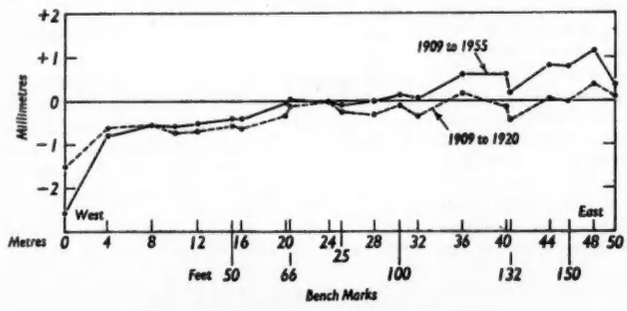


Fig. 7—Changes in levels of the bench marks

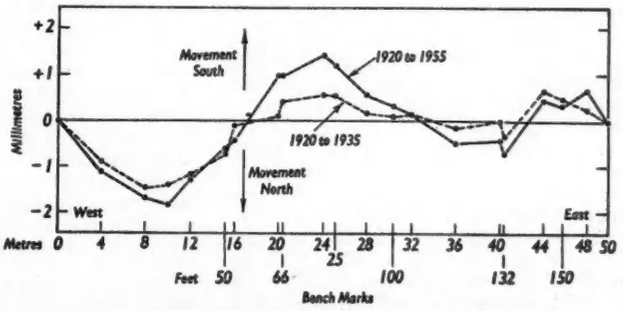


Fig. 8—Changes in the alignment of the bench marks

1920, 1935 and 1955. The measurements in each case were made relative to a tightly stretched filament and the results have been reduced to relate to a straight line joining the bench marks 0m and 50m. From these measurements the changes in alignment which have occurred have been calculated and these are shown graphically in Fig. 8. At about the 10m mark the bench receded by about 1·5mm between 1920 and 1935, but the movement was not continued to any great extent after 1935. On the other hand, the centre of the bench has moved uniformly forward throughout the whole period 1920 to 1955, the total movement being about 1·5mm.

Conclusion

The bench lengthened by 12mm in forty-two years and is still lengthening at the rate of about 0·2mm per year. During the summer it lengthens by about 0·5mm, but during the remainder of the year a contraction of about 0·3mm takes place. As a whole the bench has tilted downwards at the west end by about 2mm and the vertical distortion has been small except at the extreme west end, where a relative local drop of 1·5mm has occurred. The lateral alignment has altered in a rather irregular manner, but in no case has the alteration exceeded 2mm.

Acknowledgment

This review has been prepared as part of the research programme of the National Physical Laboratory and is published by permission of the Director of the Laboratory.

References

[1] Clark, J. S. 1950, The Engineer, Vol. 189, No. 4908, p. 201 and No. 4909, p. 228.
[2] Clark, J. S., and Johnson, L. O. C. 1953, The Engineer, Vol. 196, No. 5092, p. 260.

Lloyd's Shipbuilding Returns

Lloyd's Register has published its shipbuilding returns for the quarter ended March 31. In Great Britain and Northern Ireland a total of 348 steamships and motorships of 2,086,262 tons gross was under construction and during the quarter 75 ships of 298,563 tons were commenced, 53 ships of 224,945 tons were launched and 54 ships of 349,303 tons were completed. Ships preparing but not commenced amounted to 2,384,485 tons, of which oil tankers accounted for 57·7 per cent. Of the total tonnage being built in this country 73 ships of 467,010 tons, or 22·4 per cent, is for registration abroad. Oil tankers total 68 ships of 877,110 tons gross, which represents 42·0 per cent of the total tonnage building.

Abroad, the work in hand amounted to 1250 ships of 6,295,435 tons, an increase of 365,585 tons over the previous quarter. The totals of ships commenced, launched and completed were respectively 378 ships of 1,708,660 tons, 375 ships of 1,617,113 tons, and 367 ships of 1,371,552 tons, of which Japan's share was 586,545 tons launched and 481,172 tons completed. Of the total under construction 2,890,899 tons, or 45·9 per cent, were for registration outside the country where being built. At 2,852,024 tons for 209 ships, oil tankers represented 45·3 per cent of the tonnage building and an increase of 316,814 tons since the end of December. Throughout the world 1598 ships of 8,381,697 tons were under construction, of which this country's share is 24·9 per cent, 316,629 tons more than for the previous quarter. Of the total, oil tankers accounted for 277 ships of 3,729,134 tons, or 44·5 per cent of the total tonnage.

Distribution Method for Circular Cylindrical Shells

By J. C. de C. Henderson and E. Kemp

This article is an account of an edge disturbance distribution method devised by R. S. Jenkins for the solution of the single shell or the multiple-shell roof system. The disturbance waves are separated by considering the "other" edge to be infinitely distant, instead of being fixed as in Hardy Cross's moment distribution method. The notation has been chosen to emphasise the origins of these separated waves, in order to maintain a clear physical picture of the process. It is assumed that the reader is familiar with the elastic theory of the cylindrical shell and with the algebraic and numerical manipulation of matrices. These matrices,† used as linear operators, dominate the method and make it practicable to solve this and other similar complex linear problems. Though this method has been specially designed for the calculation of reinforced concrete shells, it is equally applicable to similar problems in steel construction, since an elastic homogeneous section has necessarily been assumed.*

Structural analysis is concerned in the first instance with the study of the mechanical properties of individual components, and then with the properties of connected systems. The equations which express these properties are fortunately often linear, provided suitable physical assumptions are made. The dominant idea throughout linear theory is that of the linear operator, and consequently its mathematical representation is of fundamental importance. A large class of these operators can be represented by matrices. The elements of these matrices, which are themselves linear operators, may be the coefficients of a co-ordinate transformation, algebraic expressions, or indeed the operators of differentiation or integration.

Not unnaturally, the mathematics of linear analysis embraces all linear problems whatever their specific nature. Thus, problems which are seemingly dissimilar in character may require the same basic mathematics for their solution. The engineer is not, of course, expected to make a special study of abstract linear analysis, but some realisation of its generality cannot but be an advantage. For convenience in this article we will refer to structural linear analysis as structural analysis since no confusion can arise.

There are in general three possible approaches to the solution of the problems of structural analysis :

(1) An "exact" method, involving a direct solution of a set of linear equations by matrix inversion or an equivalent technique.

(2) A "series" method, being a convergent iterative process such as that in Hardy Cross's moment distribution.

(3) A "variational" method which is equivalent to minimising an integral, as, for example, in the Rayleigh-Ritz method, or in Southwell's relaxation solution of differential equations.

The method we give now is R. S. Jenkins's series solution for the single shell or multiple shell system. It is analogous to that of Hardy Cross's moment distribution but here the distribution is more complex, involving not one stress-resultant, but four.

A knowledge of an eighth order linear partial differential equation for the circular cylindrical shell is assumed. It is irrelevant to the argument which particular equation is chosen, providing it is amenable to the usual initial procedure, which consists first of the appropriate separation of the variables by means of a Fourier expansion in the longitudinal direction of the shell. The problem is thus reduced to the solution of an ordinary differential equation describing disturbances along the central segment of the shell. Since the Fourier series is constructed to make the solution fit prescribed boundary conditions on the gables, the problem is concerned only with satisfying the boundary conditions on the generator edges of the shell. These conditions are in general dictated by the elastic properties of the adjoining structure or structures. It is from this stage that the methods for solving shell problems go their various ways to reach their objectives by quite different routes.

One of two physical assumptions must be made at this point, namely, whether a disturbance "travelling" from an edge is, or is not, affected by its own reflections from the other edge.

A choice in the way of dealing with the arbitrary constants of the complementary function is left open by both assumptions. These constants may be evaluated numerically by a direct process considering the appropriate boundary conditions, or they may be eliminated entirely, in terms of edge disturbances. In the latter case, the disturbances may be either stress-resultants or displacements.

The present method assumes that disturbances are affected by their reflections from the other edge and that the arbitrary constants are eliminated in terms of edge displacements. The conventions used for the shell axes, for stress-resultants, and for displacements are shown in Fig. 1.

Using the Kirchhoff boundary conditions[1] for the shell edge, we have to consider four stress-resultants and four displacements acting along each generator. These stress-resultants and displacements are denoted by $\mathbf{x}=\{x_1, x_2, x_3, x_4\}$ and $\mathbf{u}=\{u_1, u_2, u_3, u_4\}$ respectively. It is not necessarily an advantage to work with the actual stress-resultants or displacements since these may be more conveniently replaced by some function of themselves, such as a derivative with respect to the x direction. Jenkins's stress-resultants or displacement functions are adopted here, chiefly because of their advantage in connection with the translatory transformations described later. The x and u are given by :

$$\mathbf{x}=\{x_1, x_2, x_3, x_4\}=\left\{-\frac{\partial n_{12}}{\partial x}, r_2, n_2, m_2\right\}$$

$$\mathbf{u}=\{u_1, u_2, u_3, u_4\}=\left\{E\frac{\partial u}{\partial x}, E\frac{\partial^2 w}{\partial x^2}, E\frac{\partial^2 v}{\partial x^2}, E\frac{\partial^3 \theta}{\partial x^3}\right\}.$$

These are even functions in the x direction

[1] $r_2 = q_2 - \frac{\partial m_{12}}{\partial x}$.

* *Theory and Design of Cylindrical Shell Structures.* R. S. Jenkins. Published privately, 1947.

† Notation : column or row matrices are given in bold face type.

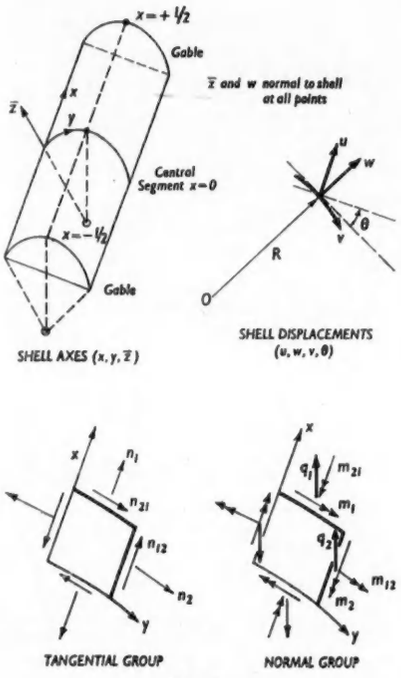


Fig. 1

taken about the $x=0$ line. Since the problems which concern us are symmetric about this line, the Fourier expansion in the x direction can be a half range cosine series.

A typical term of the complete complementary function may be expressed as:

$$Y_n(y)X_n(x)=Y_n(y)\cos\alpha_n x$$

where

$$\alpha_n=\frac{n\pi}{l},\ (n=1,\ 3,\ 5\ \ldots.)$$

where in real form

$$\begin{aligned}Y_n(y)=&e^{-j\lambda y}(f_1\cos k\lambda y+f_2\sin k\lambda y)\\&+e^{-j_1\lambda y}(f_3\cos k_1\lambda y+f_4\sin k_1\lambda y)\\&+e^{-j\lambda z}(g_1\cos k\lambda z+g_2\sin k\lambda z)\\&+e^{-j_1\lambda z}(g_3\cos k_1\lambda z+g_4\sin k_1\lambda z),\end{aligned}$$

where j, j_1, k, k_1 are dependent on the roots of the auxiliary equation and λ is a shell constant. These are also dependent on the α_n term used according to the particular value of n in the Fourier expansion. We will only consider here $n=1$, since the first term of the expansion is sufficient for most purposes, and f_1, f_2, f_3, f_4; g_1, g_2, g_3, g_4 are the arbitrary constants of the complementary

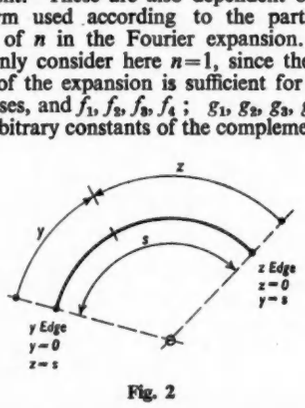


Fig. 2

function, and $y+z=s$ is the length of the shell arc shown in Fig. 2.

The complementary function is thus expressed as the sum of two damped waves generated from the y and z edges.

Let

$$\begin{aligned}l_1(y)&=e^{-j\lambda y}\cos k\lambda y\\l_2(y)&=e^{-j\lambda y}\sin k\lambda y\\l_3(y)&=e^{-j_1\lambda y}\cos k_1\lambda y\\l_4(y)&=e^{-j_1\lambda y}\sin k_1\lambda y\end{aligned}$$

similarly for $l_1(z)$, &c., and also let

$$\mathbf{f}=\{f_1\ f_2\ f_3\ f_4\}$$
$$\mathbf{g}=\{g_1\ g_2\ g_3\ g_4\}$$

Using these expressions and the appropriate functions of $Y_n(y)\cos\alpha_n x$, $\mathbf{x}$ and $\mathbf{u}$ may be expressed as

$$\mathbf{x}=AL^y\mathbf{f}-JAL^z\mathbf{g}$$
$$\mathbf{u}=BL^y\mathbf{f}+JBL^z\mathbf{g},$$

where A and B are constant matrices[2] of the order (4×4) and

$$L^{y\text{ or }z}=\begin{bmatrix}l_1 & l_2 & . & .\\ -l_2 & l_1 & . & .\\ . & . & l_3 & l_4\\ . & . & -l_4 & l_3\end{bmatrix}_{(y\text{ or }z)}$$

and $J=dg\ (1,\ 1,\ -1,-1)$.

Now let

$$\mathbf{y}=AL^y\mathbf{f};\qquad \mathbf{z}=-JAL^z\mathbf{g},$$

and

$$\mathbf{v}=BL^y\mathbf{f};\qquad \mathbf{w}=JBL^z\mathbf{g}.$$

Hence the complementary function values of the generator stress resultants and displacements become

$$\mathbf{x}=\mathbf{y}+\mathbf{z}$$
$$\mathbf{u}=\mathbf{v}+\mathbf{w}$$

the total solution on a generator is then given by

$$\mathbf{x}^T=\mathbf{x}+\mathbf{x}^0=\mathbf{y}+\mathbf{z}+\mathbf{x}^0$$
$$\mathbf{u}^T=\mathbf{u}+\mathbf{u}^0=\mathbf{v}+\mathbf{w}+\mathbf{u}^0,$$

where $\mathbf{x}^0$ and $\mathbf{u}^0$ are the particular integrals for the point considered. To make the total solutions complete we have, of course, to multiply the $\mathbf{x}^T$ and $\mathbf{u}^T$, which are the functions of y and z only, by the appropriate term in the Fourier expansion in the x direction, so that

$$\mathbf{x}^T(x_1y_1z)=\mathbf{x}^T(y_1z)\cos\alpha_n x=\mathbf{x}^T\cos\alpha_n x$$

and

$$\mathbf{u}^T(x_1y_1z)=\mathbf{u}^T(y_1z)\cos\alpha_n x=\mathbf{u}^T\cos\alpha_n x.$$

Examination of the above will show that if, in the expression $\mathbf{x}=\mathbf{y}+\mathbf{z}$, y tends to infinity from the y edge, then $\mathbf{z}\to0$ and $\mathbf{x}=\mathbf{y}$. Similarly, if z tends to infinity from the z edge, then $\mathbf{y}\to0$ and $\mathbf{x}=\mathbf{z}$. The same kind of argument applies to the $\mathbf{v}$ and $\mathbf{w}$ disturbance waves. We can therefore say that if the "other" edge is infinitely distant the $\mathbf{y}$ and $\mathbf{z}$ disturbances can be treated separately and the same also obtains for $\mathbf{v}$ and $\mathbf{w}$.

As is well known, the Hardy Cross "other" end is fixed. If, however, this method were adopted here the formulæ required for "carry over" purposes would be very complex compared with those used for separated disturbances. The convergence is not necessarily as quick as would be obtained for the fixed "other" edge condition, but the extra simplification of the formulæ is well worth while. It can be shown that the method always results in a convergent series for any edge beam or shell arrangement, but here there are some cases which render an "exact" method preferable. Mention will be made of these later. Table I gives a list of linear operators together with the stress-resultant displacement relations required in the distribution table. Fig. 3 shows a typical central segment ($x=0$) of a shell labelled j and k at its edges. The jk subscripts are used as labels for the stress resultants, displacements and linear operators. Fig. 4 gives the nomenclature for the shell and junction axes.

In Table I S and $F(=S^{-1})$ are stiffness

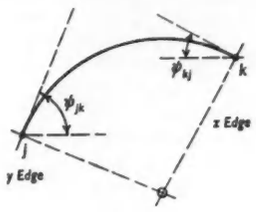


Fig. 3

TABLE I—(*Shell jk*)

Waves originating from y edge j ("other" edge at infinity)	Waves originating from x edge k ("other" edge at infinity)
$\mathbf{y}_0=AL^y\mathbf{f}$ (see below)	$\mathbf{z}_0=-JAL^z\mathbf{g}$ (see below)
$\mathbf{v}_0=BL^y\mathbf{f}$	$\mathbf{w}_0=JBL^z\mathbf{g}$
Therefore $\mathbf{v}_{y=0}=B\mathbf{f}$	$\mathbf{w}_{z=0}=JB\mathbf{g}$
since $L^{y=0}=I=dg\ (1,1,1,1)$	since $L^{z=0}=I=dg\ (1,1,1,1)$
Therefore $\mathbf{y}_0=AL^yB^{-1}\mathbf{v}_{y=0}$	Therefore $\mathbf{z}_0=-JAL^zB^{-1}J\mathbf{w}_{z=0}$
or for $y=0$	or for $z=0$
$\mathbf{y}_{y=0}=AB^{-1}\mathbf{v}_{y=0}$	$\mathbf{z}_{z=0}=-JAB^{-1}J\mathbf{w}_{z=0}$
let $S_{jk}=AB^{-1}$	let $S_{kj}=-JAB^{-1}J$
and $\mathbf{y}_{y=0}=\mathbf{y}_{jk}$; $\mathbf{v}_{y=0}=\mathbf{v}_{jk}$	and $\mathbf{z}_{z=0}=\mathbf{z}_{kj}$; $\mathbf{w}_{z=0}=\mathbf{w}_{kj}$
Therefore $\mathbf{y}_{jk}=S_{jk}\mathbf{v}_{jk}$ . . . (1)	Therefore $\mathbf{z}_{kj}=S_{kj}\mathbf{w}_{kj}$ . . (1a)
(1) and (1a) are the stress-resultant displacement edge relation in Shell axes.	
similarly $\mathbf{v}_0=BL^yB^{-1}\mathbf{v}_{y=0}$	similarly $\mathbf{w}_0=JBL^zB^{-1}J\mathbf{w}_{z=0}$
let $\mathbf{v}_0=T_{jk}{}^y\mathbf{v}_{y=0}$	let $\mathbf{w}_0=T_{kj}{}^z\mathbf{w}_{z=0}$
Therefore $\mathbf{v}_{y=0}=T_{jk}{}^y\mathbf{v}_{y=0}$	Therefore $\mathbf{w}_{z=0}=T_{kj}{}^z\mathbf{w}_{z=0}$
and let $\mathbf{v}_{y=0}=\mathbf{v}_{kj}$	and let $\mathbf{w}_{z=0}=\mathbf{w}_{jk}$
Therefore $\mathbf{v}_{kj}=T_{jk}{}^y\mathbf{v}_{jk}$ . . . (2)	Therefore $\mathbf{w}_{jk}=T_{kj}{}^z\mathbf{w}_{kj}$ . . (2a)
$T_{jk}{}^y$ and $T_{kj}{}^z$ are transfer or "carry-over" matrices for displacements in shell axes. The transformations required to change (1) and (1a) to general shell axes are: (details given at end of list).	
$Y_{jk}=-0_{jk}(\psi_{jk})\,\mathbf{y}_{jk}$	$Z_{kj}=0_{kj}(-\psi_{kj})\,\mathbf{z}_{kj}$
and $\mathbf{v}_{jk}=0_{jk}{}^T(\psi)V_{jk}$ see below	and $\mathbf{w}_{kj}=0_{kj}{}^T(-\psi)W_{kj}$
Therefore $Y_{jk}=-0_{jk}(\psi)\,S_{jk}0_{jk}{}^T(\psi)V_{jk}$	Therefore $Z_{kj}=0_{kj}(-\psi)\,S_{kj}0_{kj}(-\psi)W_{kj}$
or $Y_{jk}=-S_{jk}V_{jk}$ . . . (3)	or $Z_{kj}=-S_{kj}W_{kj}$ . . (3a)
i.e. $S_{jk}=0_{jk}(\psi)\,S_{jk}\,0_{jk}{}^T(\psi)$	i.e. $S_{kj}=-0_{kj}(-\psi)S_{kj}0_{kj}{}^T(-\psi)$
$\mathbf{y}_0$ means $\mathbf{y}$ at y	$\mathbf{z}_0$ means $\mathbf{z}$ at z
$\mathbf{v}_0$ means $\mathbf{v}$ at y	$\mathbf{w}_0$ means $\mathbf{w}$ at z
Superscript T stands for transpose	dg≡diagonal
The transformations required to change (3) and (3a) to junction axes are: (note for junction axes see Fig. 4).	
$\overline{Y}_{jk}=C_{jk}Y_{jk}$	$\overline{Z}_{kj}=C_{kj}Z_{kj}$
(*N.B.*—$\overline{Y}_{jk}$ holds Y_{jk} in equilibrium)	(*N.B.*—$\overline{Z}_{kj}$ holds Z_{kj} in equilibrium)
and $V_{jk}=C_{jk}{}^T\overline{V}_{jk}$	and $W_{kj}=C_{kj}{}^T\overline{W}_{kj}$
Therefore $\overline{Y}_{jk}=-C_{jk}S_{jk}C_{jk}{}^T\overline{V}_{jk}$	Therefore $\overline{Z}_{kj}=-C_{kj}S_{kj}C_{kj}{}^T\overline{W}_{kj}$
or $\overline{Y}_{jk}=-\overline{S}_{jk}\overline{V}_{jk}$ . . (4)	or $\overline{Z}_{kj}=-\overline{S}_{kj}W_{kj}$ . . (4a)
let $K_{jk}=C_{jk}0_{jk}(\psi)$	let $K_{kj}=C_{kj}0_{kj}(-\psi)$
then $\overline{S}_{jk}=K_{jk}\,S_{jk}K_{jk}{}^T$	then $\overline{S}_{kj}=-K_{kj}\,S_{kj}K_{kj}{}^T$

[2] The A and B are not the same as those used by Jenkins, since these include Jenkins's constant multipliers M, N, $\frac{l^3}{2\sqrt{3}}$ &c. This is done for convenience in the analytical work. The numerical calculations do, however, require separation.

TRIPLE SHELL DISTRIBUTION TABLE

TRIPLE SHELL DISTRIBUTION TABLE

	Junction 1	Edge 12	Edge 21	Junction 2	Edge 23	Edge 32	Junction 3	Edge 34	Edge 43	Junction 4
First stage :										
1 Initial P.1. stress resultants	—	$\mathbf{x}_{12}^0$	$\mathbf{x}_{21}^0$	—	$\mathbf{x}_{23}^0$	$\mathbf{x}_{32}^0$	—	$\mathbf{x}_{34}^0$	$\mathbf{x}_{43}^0$	—
2 State P.1. displacements	—	$\mathbf{u}_{12}^0$	$\mathbf{u}_{21}^0$	—	$\mathbf{u}_{23}^0$	$\mathbf{u}_{32}^0$	—	$\mathbf{u}_{34}^0$	$\mathbf{u}_{43}^0$	—
3 State P.1. beam action	$\overline{X}_{11}^0$	—	—	$\overline{X}_{22}^0$	—	—	$\overline{X}_{33}^0$	—	—	$\overline{X}_{44}^0$
4 Restore continuity	—	$\mathbf{y}_{12}^1 = S_{12}(-\mathbf{u}_{12}^0)$	$\mathbf{z}_{21}^1 = S_{21}(-\mathbf{u}_{21}^0)$	—	$\mathbf{y}_{23}^1 = S_{23}(-\mathbf{u}_{23}^0)$	$\mathbf{z}_{32}^1 = S_{32}(-\mathbf{u}_{32}^0)$	—	$\mathbf{y}_{34}^1 = S_{34}(-\mathbf{u}_{34}^0)$	$\mathbf{z}_{43}^1 = S_{43}(-\mathbf{u}_{43}^0)$	—
5 Total edge stress resultants	—	$\mathbf{y}_{12}^1 + \mathbf{x}_{12}^0$	$\mathbf{z}_{21}^1 + \mathbf{x}_{21}^0$	—	$\mathbf{y}_{23}^1 + \mathbf{x}_{23}^0$	$\mathbf{z}_{32}^1 + \mathbf{x}_{32}^0$	—	$\mathbf{y}_{34}^1 + \mathbf{x}_{34}^0$	$\mathbf{z}_{43}^1 + \mathbf{x}_{43}^0$	—
6 Transform to actions, junction axes	—	$\overline{Y}_{12}^1 = K_{12}(\mathbf{y}_{12}^1 + \mathbf{x}_{12}^0)$	$\overline{Z}_{21}^1 = -K_{21}(\mathbf{z}_{21}^1 + \mathbf{x}_{21}^0)$	—	$\overline{Y}_{23}^1 = K_{23}(\mathbf{y}_{23}^1 + \mathbf{x}_{23}^0)$	$\overline{Z}_{32}^1 = -K_{32}(\mathbf{z}_{32}^1 + \mathbf{x}_{32}^0)$	—	$\overline{Y}_{34}^1 = K_{34}(\mathbf{y}_{34}^1 + \mathbf{x}_{34}^0)$	$\overline{Z}_{43}^1 = -K_{43}(\mathbf{z}_{43}^1 + \mathbf{x}_{43}^0)$	—
7 Total junction actions	$\overline{X}_{11}^1 = \overline{Y}_{12}^1 + \overline{X}_{11}^0$	—	—	$\overline{X}_{22}^1 = \overline{Y}_{23}^1 + \overline{Z}_{22}^1 + \overline{X}_{22}^0$	—	—	$\overline{X}_{33}^1 = \overline{Y}_{34}^1 + \overline{Z}_{33}^1 + \overline{X}_{33}^0$	—	—	$\overline{X}_{44}^1 = \overline{Z}_{43}^1 + \overline{X}_{44}^0$
8 Junction displacements	$\overline{U}_{11}^1 = -\overline{F}_{11}\overline{X}_{11}^1$	—	—	$\overline{U}_{22}^1 = -\overline{F}_{22}\overline{X}_{22}^1$	—	—	$\overline{U}_{33}^1 = -\overline{F}_{33}\overline{X}_{33}^1$	—	—	$\overline{U}_{44}^1 = -\overline{F}_{44}\overline{X}_{44}^1$
9 Shell displacements due to U^1	—	$K_{12}{}^T\overline{U}_{11}^1$	$K_{21}{}^T\overline{U}_{22}^1$	—	$K_{23}{}^T\overline{U}_{23}^1$	$K_{32}{}^T\overline{U}_{33}^1$	—	$K_{34}{}^T\overline{U}_{33}^1$	$K_{43}{}^T\overline{U}_{44}^1$	—
10 Net shell edge displacements	—	$\mathbf{v}_{12}^1 = K_{12}{}^T\overline{U}_{11}^1 - \mathbf{u}_{12}^0$	$\mathbf{w}_{21}^1 = K_{21}{}^T\overline{U}_{22}^1 - \mathbf{u}_{21}^0$	—	$\mathbf{v}_{23}^1 = K_{23}{}^T\overline{U}_{23}^1 - \mathbf{u}_{23}^0$	$\mathbf{w}_{32}^1 = K_{32}{}^T\overline{U}_{33}^1 - \mathbf{u}_{32}^0$	—	$\mathbf{v}_{34}^1 = K_{34}{}^T\overline{U}_{33}^1 - \mathbf{u}_{34}^0$	$\mathbf{w}_{43}^1 = K_{43}{}^T\overline{U}_{44}^1 - \mathbf{u}_{43}^0$	—
Second stage :										
1 First stage opposite edge displacement	—	$\mathbf{w}_{21}^1$	$\mathbf{v}_{12}^1$	—	$\mathbf{w}_{32}^1$	$\mathbf{v}_{23}^1$	—	$\mathbf{w}_{43}^1$	$\mathbf{v}_{34}^1$	—
2 Second state carry over displacement	—	$\mathbf{w}_{12}^2 = T_{12}{}^S\mathbf{w}_{21}^1$	$\mathbf{v}_{21}^2 = T_{21}{}^S\mathbf{v}_{12}^1$	—	$\mathbf{w}_{23}^2 = T_{23}{}^S\mathbf{w}_{32}^1$	$\mathbf{v}_{32}^2 = T_{32}{}^S\mathbf{v}_{23}^1$	—	$\mathbf{w}_{34}^2 = T_{43}{}^S\mathbf{w}_{43}^1$	$\mathbf{v}_{43}^2 = T_{34}{}^S\mathbf{v}_{34}^1$	—
3 Total edge stress resultants	—	$\mathbf{y}_{12}^2 + \mathbf{x}_{12}^1 = (S_{12} - S_{21})(-\mathbf{w}_{12}^2)$	$\mathbf{z}_{21}^2 + \mathbf{y}_{21}^1 = (S_{21} - S_{12})(-\mathbf{v}_{21}^2)$	—	$\mathbf{y}_{23}^2 + \mathbf{x}_{23}^1 = (S_{23} - S_{32})(-\mathbf{w}_{23}^2)$	$\mathbf{z}_{32}^2 + \mathbf{y}_{32}^1 = (S_{32} - S_{23})(-\mathbf{v}_{32}^2)$	—	$\mathbf{y}_{34}^2 + \mathbf{x}_{34}^1 = (S_{34} - S_{43})(-\mathbf{w}_{34}^2)$	$\mathbf{z}_{43}^2 + \mathbf{y}_{43}^1 = (S_{43} - S_{34})(-\mathbf{v}_{43}^2)$	—
4 Transform to actions, junction axes	—	$\overline{Y}_{12}^2 = K_{12}(\mathbf{y}_{12}^2 + \mathbf{x}_{12}^1)$	$\overline{Z}_{21}^2 = -K_{21}(\mathbf{z}_{21}^2 + \mathbf{y}_{21}^1)$	—	$\overline{Y}_{23}^2 = K_{23}(\mathbf{y}_{23}^2 + \mathbf{x}_{23}^1)$	$\overline{Z}_{32}^2 = -K_{32}(\mathbf{z}_{32}^2 + \mathbf{y}_{32}^1)$	—	$\overline{Y}_{34}^2 = K_{34}(\mathbf{y}_{34}^2 + \mathbf{x}_{34}^1)$	$\overline{Z}_{43}^2 = -K_{43}(\mathbf{z}_{43}^2 + \mathbf{y}_{43}^1)$	—
5 Total junction actions	$\overline{X}_{11}^2 = \overline{Y}_{12}^2$	—	—	$\overline{X}_{22}^2 = \overline{Y}_{23}^2 + \overline{Z}_{22}^2$	—	—	$\overline{X}_{33}^2 = \overline{Y}_{34}^2 + \overline{Z}_{33}^2$	—	—	$\overline{X}_{44}^2 = \overline{Z}_{43}^2$
6 Junction displacements	$\overline{U}_{11}^2 = -\overline{F}_{11}\overline{X}_{11}^2$	—	—	$\overline{U}_{22}^2 = -\overline{F}_{22}\overline{X}_{22}^2$	—	—	$\overline{U}_{33}^2 = -\overline{F}_{33}\overline{X}_{33}^2$	—	—	$\overline{U}_{44}^2 = -\overline{F}_{44}\overline{X}_{44}^2$
7 Shell displacements due to U^2	—	$K_{12}{}^T\overline{U}_{11}^2$	$K_{21}{}^T\overline{U}_{22}^2$	—	$K_{23}{}^T\overline{U}_{23}^2$	$K_{32}{}^T\overline{U}_{33}^2$	—	$K_{34}{}^T\overline{U}_{33}^2$	$K_{43}{}^T\overline{U}_{44}^2$	—
8 Net shell edge displaeements	—	$\mathbf{v}_{12}^2 = K_{12}{}^T\overline{U}_{11}^2 - \mathbf{w}_{12}^2$	$\mathbf{w}_{21}^2 = K_{21}{}^T\overline{U}_{22}^2 - \mathbf{v}_{21}^2$	—	$\mathbf{v}_{23}^2 = K_{23}{}^T\overline{U}_{23}^2 - \mathbf{w}_{23}^2$	$\mathbf{w}_{32}^2 = K_{32}{}^T\overline{U}_{33}^2 - \mathbf{v}_{32}^2$	—	$\mathbf{v}_{34}^2 = K_{34}{}^T\overline{U}_{33}^2 - \mathbf{w}_{34}^2$	$\mathbf{w}_{43}^2 = K_{43}{}^T\overline{U}_{44}^2 - \mathbf{v}_{43}^2$	—
Third stage (repeat as second stage) :										
1 Second stage opposite edge displacement	—	$\mathbf{w}_{21}^2$	$\mathbf{v}_{12}^2$	—	$\mathbf{w}_{32}^2$	$\mathbf{v}_{23}^2$	—	$\mathbf{w}_{43}^2$	$\mathbf{v}_{34}^2$	—
Final summation after convergence	$\Sigma\overline{U}_{11}$	$\Sigma\mathbf{v}_{12}$	$\Sigma\mathbf{w}_{21}$	$\Sigma\overline{U}_{22}$	$\Sigma\mathbf{v}_{23}$	$\Sigma\mathbf{w}_{32}$	$\Sigma\overline{U}_{33}$	$\Sigma\mathbf{v}_{34}$	$\Sigma\mathbf{w}_{43}$	$\Sigma\overline{U}_{44}$

The detailed transformations used in Table I are :

$$0_{ra}(\psi_{ra}) = \begin{bmatrix} 1 & \cdot & \cdot & \cdot \\ \cdot & \cos\psi & \sin\psi & \cdot \\ \cdot & -\sin\psi & \cos\psi & \cdot \\ \cdot & \cdot & \cdot & 1 \end{bmatrix} \quad 0_{br}(-\psi_{br}) = \begin{bmatrix} 1 & \cdot & \cdot & \cdot \\ \cdot & \cos\psi & -\sin\psi & \cdot \\ \cdot & \sin\psi & \cos\psi & \cdot \\ \cdot & \cdot & \cdot & 1 \end{bmatrix}$$

where ψ is the angle between the tangent to the shell concerned and the horizontal.

$$C_{ja} \text{ or } C_{kj} = \begin{bmatrix} 1 & \cdot & \cdot & \cdot \\ -\bar{Z} & 1 & \cdot & \cdot \\ -\bar{Y} & \cdot & 1 & \cdot \\ \cdot & \bar{Y} & -\bar{Z} & 1 \end{bmatrix}$$

where $\bar{Y}$, $\bar{Z}$ are the co-ordinates (correct signs to be inserted) of the shell edge.

The *C. of G.* of the beam is the origin of the junction axes.

The edge beam internal stress-resultant displacement relations (see Fig. 5) are :

$$\begin{bmatrix} \frac{\partial^3 \bar{N}_x}{\partial x^3} \\ \frac{\partial^3 \bar{M}_y}{\partial x^3} \\ \frac{\partial^3 \bar{M}_z}{\partial x} \\ -\frac{\partial \bar{M}_x}{\partial x} \end{bmatrix} = -\alpha^3 \begin{bmatrix} A_x & \cdot & \cdot & \cdot \\ \cdot & I_y & \cdot & \cdot \\ \cdot & \cdot & I_z & \cdot \\ \cdot & \cdot & \cdot & \frac{1}{\alpha^2} I_x \end{bmatrix} \begin{bmatrix} E\frac{\partial \bar{U}}{\partial x} \\ E\frac{\partial^2 \bar{W}}{\partial x^2} \\ E\frac{\partial^2 \bar{V}}{\partial x^2} \\ E\frac{\partial^2 \bar{\Theta}}{\partial x^2} \end{bmatrix}$$

or $\bar{X}_b = -\bar{S}_b \bar{U}_b \qquad \alpha = \frac{n\pi}{l}$ as before

where EA_x, EI_y EI_z are the rigidities in direct stress and bending, and EI_x = the torsional rigidity of the beam. Plane sections are assumed to remain plane and the twist rotation is also assumed to be unaccompanied by longitudinal displacements. If a more elaborate theory is used this would entail either amendments to the $\bar{S}_b$ matrix, or the complete treatment of the edge beam as a thin plate.

and flexibility matrices respectively. In shell axes the edge relationship is in the form : stress-resultant = (+) stiffness matrix × displacement. In general shell axes or junction axes the relationship is always written in the form stress-resultant = (−) stiffness matrix × displacement.

It is easy to remember that the minus sign occurs whenever we are using capital letters to denote stress-resultants and displacements.

If the two shells *hj* and *jk* meet at junction *j* on beam *j* then the total stiffness of the *j* junction, assuming the " other " edges to be at infinity, is the sum of the individual stiffnesses, that is,

$$\bar{S}_{jj} = \bar{S}_{jh} + \bar{S}_{bj} + \bar{S}_{jk} \text{ (where } bj \equiv \text{beam } j),$$

where each stiffness is referred to the junction axes.

The flexibility of the junction in the junction axes will therefore be

$$\bar{F}_{jj} = \bar{S}_{jj}^{-1},$$

and the junction stress-resultant displacement relationship will be

$$\bar{X}_{jj} = -\bar{S}_{jj} \bar{U}_{jj},$$

where $\bar{X}_{jj}$ is the total set of stress-resultants acting on the junction and $\bar{U}_{jj}$ is the resulting displacement of the junction as a whole while maintaining geometric compatibility between its components.

The distribution Table II gives the necessary instructions to obtain the series solution for the complementary function for a triple shell arrangement on edge beams. The system is not necessarily symmetric. If it is symmetric the work can be reduced considerably by using the following symmetric expressions at shell edges :—

For stress-resultants, $\mathbf{x}_{jk} = -J\mathbf{x}_{kj}$.

For displacements, $\mathbf{u}_{jk} = J\mathbf{u}_{kj}$.

The same relations hold for the separated waves, **y**, **z** and **v**, **w**. All the results obtained from the distribution must, of course, be combined with the particular integral to give the total solution. Keeping in mind the Hardy Cross moment distribution analogy, we will now describe the shell distribution table line by line.

First Stage :

Line 1.—Edge stress-resultant particular integrals for shell edges.

Line 2.—Edge displacement particular integrals for shell edges.

Line 3.—Beam particular integral. This is the self weight of the beam acting on a temporarily " propped " unstrained straight beam. For the arrangement of beams shown in the diagram of Table I the only term will be the second component of $\bar{X}_b^0$ and is equal to the negative of its weight per unit run multiplied by $4/\pi$. This multiplier is appropriate for the first term in the Fourier expansion in the x direction.

Line 4.—The application of the $\mathbf{y}^1$ and $\mathbf{z}^1$ brings the shell edges back to the unstrained datum position. The shell edges are now against the top of the unstrained edge beams.

Line 5.—The total edge stress-resultant is now the sum of those just imposed (line 4) and those which are already there (line 1).

Line 6.—The stress-resultants required to hold a y edge on the unstrained " propped " edge beam is given by $-K_{jk}(\mathbf{y}_{jk}^1 + \mathbf{x}_{jk}^0)$ in junction axes, and a z edge by $K_{kj}(\mathbf{z}_{kj}^1 + \mathbf{x}_{kj}^0)$. To release these stress-resultants we require the application of their equal and opposite, that is, the actions $k_{jk}(\mathbf{y}_{jk}^1 + \mathbf{x}_{jk}^0)$ and $-K_{kj}(\mathbf{z}_{kj}^1 + \mathbf{x}_{kj}^0)$.

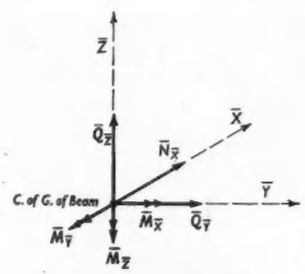
Line 7.—X_{jj}^1 is the total action from the beam and shell edges to be released.

Line 8.—All restraints are now removed and the junction is allowed to move freely as a whole to an equilibrium position. The shells and beams stay in contact since the stress-resultants imparted to them are in proportion to their various stiffnesses.

Line 9.—The movement $\bar{U}^1$ of each junction (maintaining geometric compatibility) causes shell movements of $K_{jk}{}^T \bar{U}_{jj}^1$ for a y edge, and $K_{kj}{}^T \bar{U}_{kj}^1$ for a z edge.

Line 10.—The net shell edge displacement is the actual movement caused by the applied edge stress-resultants of the complementary function during stage 1.

It must be remembered that all the above operations have been performed assuming that the " other " edge is at infinity. These



BEAM INTERNAL STRESS-RESULTANTS IN JUNCTION AXES.

Fig. 5

operations, however, will have caused disturbances at a distance S from the edge under consideration, so that geometric and stress compatibility of the shells and beam at the " other " edge will have been lost. The second stage is concerned with the restoration of this compatibility.

The second state is now formed by calculating the " other " edge disturbances caused by the operations of stage 1.

Second Stage.—The operations as set out in the table are considerably contracted for speed of computation. Lines 1*a*, 2*a*, 2*b* have been omitted and are described in conjunction with the others below.

Line 1.—The net shell edge displacements

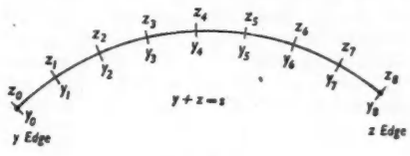


Fig. 6

of stage 1 are rewritten in the " other " edge column for computational convenience.

Line 1*a*.—Because of the $\mathbf{w}_{kj}^1$ and $\mathbf{v}_{jk}^1$ there will be stress-resultants $\mathbf{z}_{jk}^1$ and $\mathbf{y}_{kj}^1$ at the y and z edges which are given by

$$\mathbf{z}_{jk}^1 = \bar{S}_{kj}{}^s \mathbf{w}_{kj}^1 = \bar{S}_{kj} T_{kj}{}^s \mathbf{w}_{kj}^1, \text{ [a]}$$

and

$$\mathbf{y}_{kj}^1 = \bar{S}_{jk}{}^s \mathbf{v}_{jk}^1 = \bar{S}_{jk} T_{jk}{}^s \mathbf{v}_{jk}^1.$$

Line 2.—The carry over displacements at the y and z edges are given by

$$\mathbf{w}_{jk}{}^2 = T_{kj}{}^s \mathbf{w}_{kj}^1 \text{ and } \mathbf{v}_{kj}{}^2 = T_{jk}{}^s \mathbf{v}_{jk}^1.$$

Line 2*a*.—The geometric discontinuities $\mathbf{w}_{jk}{}^2$ and $\mathbf{v}_{kj}{}^2$ are removed by the application

[a] $\mathbf{x}_{rs}$ is the value of a **x** wave which starts from the $k(z)$ edge and has reached the $j(y)$ edge when $z = s$.

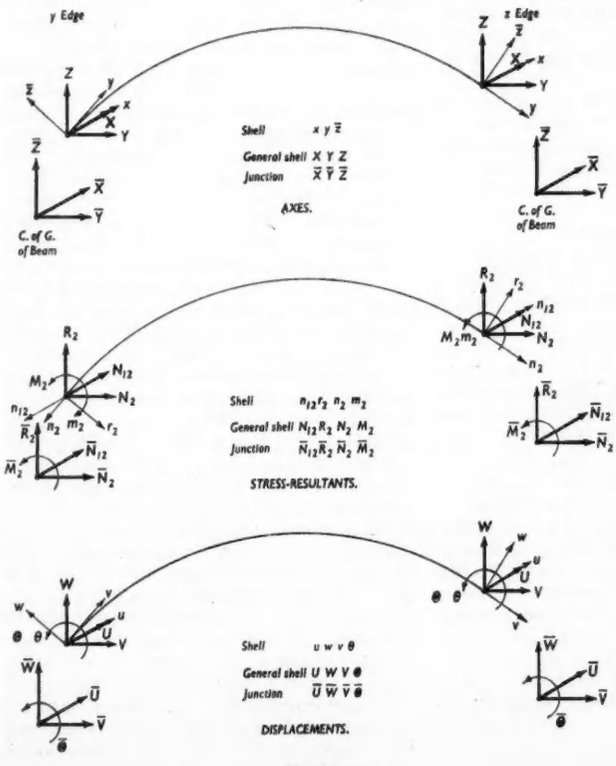


Fig. 4

of stress-resultants at the y and z edges given by

$$\mathbf{y}_{jk}{}^{2}=\bar{S}_{jk}(-\mathbf{w}_{jk}{}^{2}) \text{ and } \mathbf{z}_{kj}{}^{2}=\bar{S}_{kj}(-\mathbf{v}_{kj}{}^{2}).$$

Line 2*b*.—The total stress-resultants now on a y edge are given by

$$\begin{aligned}\mathbf{y}_{jk}{}^{2}+\mathbf{z}_{jk}{}^{2}&=\bar{S}_{jk}(-\mathbf{w}_{jk}{}^{2})+\bar{S}_{kj}(T_{kj}{}^{s}\,\mathbf{w}_{kj}{}^{1})\\&=\bar{S}_{jk}(-\mathbf{w}_{jk}{}^{2})+\bar{S}_{kj}(\mathbf{w}_{jk}{}^{2})\end{aligned}$$

Line 3.—

$$=(\bar{S}_{jk}-\bar{S}_{kj})(-\mathbf{w}_{jk}{}^{2}).$$

similarly the total stress-resultants now on a z edge are given by

$$\mathbf{z}_{kj}{}^{2}+\mathbf{y}_{kj}{}^{1}=(\bar{S}_{kj}-\bar{S}_{jk})(-\mathbf{v}_{kj}{}^{2}).$$

Line 4.—The total stress-resultants of line 3 are transformed to actions in junction axes as in stage 1, line 6.

The remainder of stage 2 follows the pattern of stage 1. On reaching the end of stage 2, the magnitude of the net displacements should be compared with those of stage 1. They will generally be diminished but not necessarily so as in the case of tilted shells, when the lower edge displacements may increase and those of the upper edge decrease.

The procedure of stages 3, 4, &c., repeats that of stage 2. The distribution is continued until the various net $\mathbf{v}$ and $\mathbf{w}$ are considered small enough to neglect. The total separated net edge displacements are $\Sigma\mathbf{v}$ and $\Sigma\mathbf{w}$, and the total junction displacements are $\Sigma\overline{U}$.

This account is completed with a brief description of Jenkins's computational arrangement for the determination of the shell stress-resultants and displacements at various positions of the shell using $\Sigma\mathbf{v}$ and $\Sigma\mathbf{w}$.

For the actual stress-resultant and displacement calculation at various positions on the shell it is convenient to divide the central shell segment into n equal parts, as shown in Fig. 6.

The total $\mathbf{v}$ and $\mathbf{w}$ waves at each point of the segment are obtained from the edge total $\mathbf{v}$ and $\mathbf{w}$ waves by operating with suitable T transfer or carry over matrices. These T^{y} or T^{z} must have the correct y or z for the position considered, measured from the y or z edges respectively. In Fig. 6 the points on the segment have been labelled from 0 to 8 from the y to the z edge. If we let $y_{(1)}$ be the distance from (0) to (1) and $y_{(2)}$ be the distance from (0) to (2) and so on, then

$$\begin{aligned}\mathbf{v}_{(1)}&=T^{y(1)}\,\mathbf{v}_{(0)}\\\mathbf{v}_{(2)}&=T^{y(2)}\,\mathbf{v}_{(0)}\\&\cdots\quad\cdots\\\mathbf{v}_{(8)}&=T^{y(8)}\,\mathbf{v}_{(0)}=T^{y=z}\,\mathbf{v}_{0}=T^{z}\,\mathbf{v}_{(0)}.\end{aligned}$$

The only T matrices required, however, are $T^{y(1)}$, and T^{z} for checking, since $T^{y(2)}=T^{y(1)+y(1)}=(T^{y(1)})^{2}$, and in general $T^{y(r)}=(T^{y(1)})^{r}$.

The next step in the problem is to calculate the $\mathbf{v}$ and $\mathbf{w}$ at all the required points of the shells. The list of the collected results will be referred to as the "separated wave table." This means that for each shell we have (using eight divisions) :

$$\mathbf{v}_{(0)}\quad\mathbf{v}_{(1)}\quad\mathbf{v}_{(2)}\quad\mathbf{v}_{(3)}\quad\cdots\quad\mathbf{v}_{(8)}$$

$$\mathbf{w}_{(0)}\quad\mathbf{w}_{(1)}\quad\mathbf{w}_{(2)}\quad\mathbf{w}_{(3)}\quad\cdots\quad\mathbf{w}_{(8)}.$$

Since

$$\begin{aligned}\mathbf{x}^{T}&=\mathbf{x}+\mathbf{x}^{0}\text{ (at any point on the segment)}\\&=\mathbf{y}+\mathbf{z}+\mathbf{x}^{0}\\&=\bar{S}^{y}\,\mathbf{v}_{(0)}+\bar{S}^{z}\,\mathbf{w}_{(0)}+\mathbf{x}^{0}\text{, where } y+z=s\end{aligned}$$

and

$$\bar{S}^{s}=-J\bar{S}^{y=s}J,$$

then

$$\begin{aligned}\mathbf{x}^{T}&=\bar{S}^{y}\,\mathbf{v}_{(0)}-J\bar{S}^{y=s}J\,\mathbf{w}_{(0)}\\&=\bar{S}^{y=0}T^{y}\mathbf{v}_{(0)}-J\bar{S}^{y=0}T^{s}J\,\mathbf{w}_{(0)}\\&=\bar{S}\,\mathbf{v}_{(y)}-J\bar{S}J\,\mathbf{w}_{(s)}\\&=\tfrac{1}{2}(\bar{S}+J\bar{S})(\mathbf{v}_{y}-J\mathbf{w}_{s})+\tfrac{1}{2}(\bar{S}-J\bar{S})(\mathbf{v}_{y}+J\mathbf{w}_{s})^{4}\end{aligned}$$

where $\mathbf{v}_{(y)}$ is the value of $\mathbf{v}$ at y and conveniently written $\mathbf{v}_{y}$ and similarly, $\mathbf{w}_{(s)}=\mathbf{w}_{s}$. $\bar{S}^{y=0}=\bar{S}$ as before.

The values in the separated wave table are then substituted into the above expression for $\mathbf{x}^{T}$ in the way set out in Table III.

TABLE III

	Wave at point (r)	Matrix elements 1	2	3	4	Matrix Σ check
Line 1 ...	$\mathbf{v}-J\mathbf{w}$	x	x	x	x	
Line 2 ...	$\mathbf{v}+J\mathbf{w}$	x	x	x	x	
Line 3 ...	$\mathbf{u}^{0}$	x	x	x	x	
Line 4 ...	$\mathbf{u}^{T}$	(1)	(2)	(3)	(4)	
Line 5 ...	$\mathbf{y}+\mathbf{z}$	(5)	(6)	(7)	(8)	
Line 6 ...	$\mathbf{x}^{0}$	x	x	x	x	
Line 7 ...	$\mathbf{x}^{T}$	(9)	(10)	(11)	(12)	

Table III shows the layout required for one of the points 0 to 8 of Fig. 6. It is constructed as follows :

Lines 1 and 2.—The information is supplied from the separated wave table.

Line 3.—Particular integral displacements.

Line 4.—The total displacements $\mathbf{u}^{T}$ given as (1) and (2) are obtained by adding corresponding entries of lines 2 and 3. The results (3) and (4) are obtained by adding corresponding entries of lines 1 and 3. This is easily understood when it is remembered that $J=dg\ (1, 1, -1, -1)$.

Line 5.—(5) and (6) are obtained by operating on the results of line 1 by $\frac{1}{2}(\bar{S}+J\bar{S})$.[5] (7) and (8) are obtained by operating on the results of line 2 by $\frac{1}{2}(\bar{S}-J\bar{S})$.

Line 6.—Stress-resultant particular integral values.

Line 7.—$\mathbf{x}^{T}$ is the sum of lines 5 and 6, i.e. $\mathbf{x}+\mathbf{x}^{0}$.

It is beyond the scope of this article to describe the details of the completion of the work regarding the edge beam stresses and the various checks which can and should be made.

CONCLUSION

We would like to emphasise again that the object we have had in view is the general explanation of Jenkins's distribution method. To do this in the simplest way we can discover, we have had to alter much of Jenkins's notation. Our main change has been in the notation of the separated waves so that it is now easy to trace the various wave origins throughout the table. We mentioned earlier that the convergence may sometimes be too slow to allow the method to be used. The speed of convergence is controlled by the exponential function in the L matrix. The case is analogous to that of Hardy Cross, where the same trouble occurs for a carry over factor approaching unity. For shells, the only really troublesome cases are with short segments. Solutions by the "exact" method are given in Jenkins's book. The distribution table has been strictly designed for the kind of shells shown in the table diagram and must not be used if some of the shells are inverted. These cases can quite easily be calculated provided care is taken with the edge transformations K.

No specific mention has been made about the nature of the particular integral values since these may be derived from various sources such as self-weight, wind load, temperature effects and post-tensioning the edge beams. The numerical work required in this kind of calculation is not as difficult as might be imagined from reading the theory. The matrix methods help to keep it organised and the routines imposed are easily learnt. Calculations of this kind do not have to be done entirely by one individual. Much of the work need only be done by a trained computer without any engineering knowledge.

At the end of footnote[2] the words appear "the numerical calculations do, however, require separation." The separated matrices $\bar{A}$ and $\bar{B}$ have been tabulated by the author for twenty-one values of the shell parameter μ using the DJK equation. Copies of these tables are available upon application to The Manager, THE ENGINEER, 28, Essex Street, London, W.C.2. Price 2s.

British Non-Ferrous Metals Research Association

THE annual report of the British Non-Ferrous Metals Research Association shows that the membership had increased by nineteen to 636 by the end of 1956, and that the total grant-earning for the year exceeded that necessary to earn the maximum grant of £43,000. The Association, with the co-operation of the nuclear power consortia and the United Kingdom Atomic Energy Authority, has started research on the properties of thorium and thorium alloys as a contribution to the metallurgical problems encountered in the application of nuclear energy to power production.

A review of research progress during 1956 states that laboratory space has become seriously congested and that this will be a limiting factor in further expansion in the research department pending the erection of new buildings which have been planned. In the notes on research in connection with refining the report states that methods developed for the removal of small amounts of lead and tin from molten copper have undergone extensive trials on production, and results showed that the methods achieve the required degree of purification with much smaller copper losses than in conventional practice. In connection with methods of analysis, work is in progress with X-ray fluorescence and extension of the use of spectrographic techniques. Work carried out on melting and casting included investigations on the effect of sulphur in certain copper base alloys, the relationship between the constitution and casting characteristics of copper-base casting alloys, the factors affecting the soundness of cadmium copper billets for subsequent casting, and sand and shell moulding for copper alloys.

New work was undertaken during the year on the cold rolling characteristics of a wide range of copper alloys. Other sections of the report deal with research work concerned with instrumentation, mechanical properties, corrosion, protection, new alloys for cable sheathing, and high-temperature brazing.

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[4] The $\bar{S}$ are all y edge, i.e. $\bar{S}_{jn}$.

[5] For shell jk the expression is written $\frac{1}{2}(\bar{S}_{jn}-J\bar{S}_{jn})$, where $\bar{S}_{jn}=\bar{S}^{y=0}{}_{jn}$.

Compression Testing Machines for Concrete

By P. J. F. WRIGHT, B.Sc.*

A study has been made of the discrepancies sometimes observed when nominally similar concrete cubes are tested on two or more different machines. A major cause of these discrepancies was found in misalignment of the components of the testing machine. Other important factors are the planeness of the platens of the machine and the maintaining of a constant rate of loading right up to the failure of the specimen. The freedom of movement of self-aligning platens has also been found to affect the results ; a platen which adapts itself initially to the shape of the specimen and thereafter does not move gives less variable results than a platen which remains free to move under high loads. These points are embodied in a set of recommendations for the use of concrete compression testing machines.

FROM time to time cases have arisen where concrete test cubes made on an engineering contract have been tested on two or more testing machines and the results recorded on one machine have been consistently lower than those recorded on another. One such case is described by Graham and Martin.[1] The introduction in 1952 of British Standard 1881,[2] which details the method of testing cubes and lays down certain requirements for the testing machine, has not eliminated discrepancies of this kind, and an investigation into their magnitude and possible causes was undertaken at the Road Research Laboratory. One aspect of the work, showing how the friction in spherical seatings of compression testing machines affects the results, has already been described by Tarrant.[3,4] This article describes the remainder of the work and, although the problems associated with testing concrete in compression have not been completely solved, sufficient information has been obtained for making recommendations for the use of compresssion testing machines for concrete.

Types of Machine Used

Concrete test cubes are generally tested in machines designed specifically for the purpose ; these machines are nearly always hydraulically operated. Two single-lever machines were included in the investigation to be described ; this kind of machine is not normally used for testing cubes.

A hydraulic machine comprises a simple press provided with a self-aligning platen and a means of measuring the load. Some machines employ Bourdon gauges connected to the cylinder, others measure the force exerted by the hydraulic fluid on a small auxiliary ram. The methods of measuring this force include the displacement of a pendulum, the extension of a spring and the balancing of a steelyard. Most of the methods used lend themselves to direct load indication on a dial. Other machines measure the load in terms of the elastic deflection produced either in the structural members, generally the columns, of the machine or in a weighing ring positioned between the self-aligning platen and the fixed crosshead of the press. An advantage of the elastic measurement of load is that it eliminates errors arising from friction between the ram and cylinder of the press. Although this list is not exhaustive it indicates the diversity of the types of machine used. Several of them were included in the investigation and they are described briefly in Table II. All the machines were calibrated with the same calibrating device before being used for the investigation and appropriate corrections were made where necessary to the indicated loads. These corrections amounted, in one case, to as much as 9 per cent.

* Road Research Laboratory, Department of Scientific and Industrial Research.

Initial Comparison of Nine Machines

For the first group of tests (Series 1 in Table I) 270 4in cubes were prepared under carefully controlled conditions, in ten batches of twenty-seven. Of each batch three were tested at the age of twenty-eight days on each of the nine machines detailed in Table II. For this purpose the cubes (including those for test at the Road Research Laboratory) were immersed in tanks of saturated sand at the age of twenty-one days ± one day and transported to the various laboratories. They were then stored in water at a controlled temperature of 62 deg. Fah. maintained within ±4 deg. Fah. or less until they were ready for test. They were tested wet in the standard manner except that no special effort was made to maintain the rate of increase of stress at 2000 lb per square inch per minute as the specimens were approaching failure. There was no great difference between the average strengths obtained on the different machines, the highest average being only 4 per cent above the lowest.

Table I—*Average Results Obtained in Initial Comparison of a Number of Machines*

	Machine No.	4in cubes (Series 1), averages of 30	6in cubes (Series 2), averages of 24
Average crushing strength (pounds per square inch)	1	6500	6410
	2	6560	6380
	3	6690	6500
	4	6680	6430
	5	6520	5760
	6	6410	5910
	7	6610	—
	8	6560	—
	9	6430	—
Approximate average failing load (tons)	—	47	100

A second set of tests (Series 2) was conducted in which twenty-four 6in cubes were tested on each of the first six machines. Greater differences were recorded between the different machines than in Series 1, the highest average being 13 per cent above the lowest. More particularly the averages for the first four machines did not differ greatly one from another but their overall average was 10 per cent above the average for machines No. 5 and No. 6. Since machines No. 5 and No. 6 were similar in general design this suggested that the reduction in failing load might be due to some feature of the design and a more detailed study of these machines was made.

Effect of Tilting of the Platens.—Since a tendency had sometimes been observed for cubes to fail on one particular side when tested on one particular machine, measurements were made in the first series of tests, using 4in cubes, of the relative sideways tilting of the platens of machines 1, 2, 4, 5 and 6. This was done by means of two dial gauges mounted on heavy steel blocks along a diameter of the platen as shown in Fig. 1. The cubes were tested with the top, as-cast, facing the observer in order to provide symmetrical conditions, and the distance between the axes of the dial gauges was about 7½in, so that any differential movement indicated by the gauges was nearly twice the differential

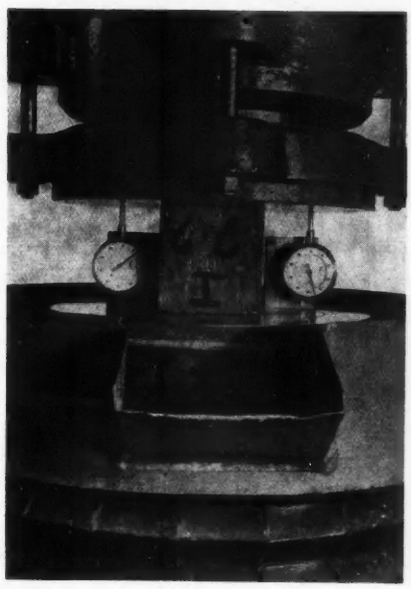

Fig. 1—Arrangement of dial gauges for measuring movements of platens

Table II—*Details of the Testing Machines Under Comparison*

Machine No.	Capacity (tons)	Method of loading	Method of weighing	Remarks
1	200	Hydraulic : motorised pump	Measurement of oil pressure by displacement of a pendulum operated through a small ram	These two machines were made by the same firm and were similar in general design and principle
2	200			
3	500	Hydraulic : hand - operated pump	Measurement of extension in main columns	These two machines were made by the same firm but differed in general design and method of weighing
4	200	Hydraulic : motorised pump	Measurement of oil pressure by extension of a spring operated through a small ram	
5	200	Hydraulic : motorised pump	Deflection of a weighing ring above the top platen. (Bourdon gauge also provided.)	These two machines were made by the same firm and were similar in general design and principle
6	250			
7	100	Hydraulic : motorised pump	By single lever ; hand-operated screw feed to poise	These two machines were made by the same firm and were similar in method of weighing
8	60	Motorised screw drive		
9	200	Hydraulic : motorised pump	Measurement of oil pressure by Bourdon gauge	—

movement between the right- and left-hand sides of the cube.

In Fig. 2 (*a*) to (*d*) typical displacement/time curves are shown for four of the machines. These curves were chosen, from the many obtained, by placing the diagrams for each machine in order of increasing differential movement and selecting one of

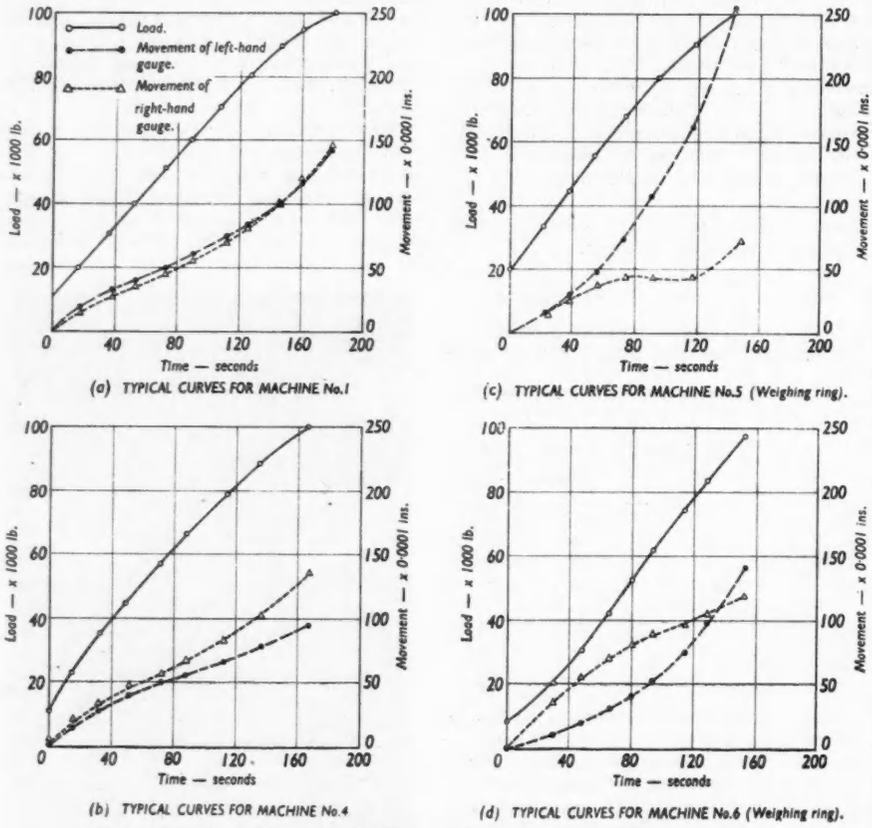
Load.
Movement of left-hand gauge.
Movement of right-hand gauge.
Load — x 1000 lb.
Movement — x 0·0001 ins.
Time — seconds
(a) TYPICAL CURVES FOR MACHINE No.1
(c) TYPICAL CURVES FOR MACHINE No.5 (Weighing ring).
(b) TYPICAL CURVES FOR MACHINE No.4
(d) TYPICAL CURVES FOR MACHINE No.6 (Weighing ring).

Fig. 2—Rate of application of load and movement of the platens on different machines

the middle two of the series. In machine No. 1 the agreement between the two sides was always very close, showing that very little tilting of the self-aligning platen took place under load. Machine No. 2 also showed very little tilting. Machine No. 4 consistently produced more movement on the right than on the left. Machine No. 5 consistently showed continuous and relatively large movement on the left while the curve for the right-hand gauge showed an inflection, as in Fig. 2 (*c*), with the slope sometimes becoming negative and, in an extreme case, the net displacement becoming negative. Machine No. 6 showed normal movement on the left-hand side, but on the right the movement was relatively rapid at first and subsequently decreased so that in nearly all the tests the two curves formed a loop, as shown in Fig. 2 (*d*).

Since the pronounced tilting observed on machines No. 5 and No. 6 was consistent in direction and character for each machine it was clearly caused by some fault in the machine. Differences in the properties of different parts of the cube can cause tilting, but such tilting would either be of a random nature or would represent, say, a greater deflection at the top of the cube, as-cast, than at the bottom. Neither of these conditions applied in the present case. The type of machine represented by Nos. 5 and 6 therefore required further examination. However, the other types of machine could, when properly used, give sensibly equal results.

Detailed Examination of Weighing Ring Machines

Since machines No. 5 and No. 6 differed from most machines in having an elastic steel weighing ring for measuring the load mounted above the self-aligning platen, it seemed possible that this might be a contributory factor in causing the lower failing loads observed on these machines. The energy stored in this ring under load might serve to intensify the cracking in a cube which occurs well before final failure, and might thus lead to a lower failing load. A machine without this reserve of energy would not follow, in the same way, the sudden movements which must occur as the cracks form. This point was examined (Series 3 in Table III) by testing thirty-six 4in cubes in machine No. 1 with a 120-ton proving ring placed between the cube and the lower platen and a further thirty-six cubes with the ring replaced by a solid steel cylinder 6in in diameter and the same height (15in) as the proving ring. The headroom in the machine did not allow 6in cubes to be tested under these conditions. The results obtained with the proving ring and with the solid cylinder agreed within 1 per cent, and it was concluded that the observed discrepancies could not be attributed to the principle of using a relatively compressible ring in the loading system.

The pronounced relative tilting of the platens observed on machine No. 5 was found to be the result of eccentric loading which arose because the axis of the weighing ring was displaced ¼in from that of the ram. It had also been noted that cubes tested in this machine consistently failed first on the side towards which the ring was displaced. Tests on 4in cubes (Series 4) placed (*a*) centrally on the lower platen and (*b*) in line with the axis of the ring, did not establish any effect due to the eccentricity, but 6in cubes (Series 5) gave 13 per cent higher strengths when they were placed in line with the ring than when tested in the normal position. The ring was re-centred over the upper platen of the machine and comparative tests were then made on this machine and on machine No. 1. Tests on 4in cubes (Series 6) again showed no significant difference, although 6in cubes (Series 7) gave 2½ per cent lower results on machine No. 5 than on machine No. 1. This difference, however, could be ignored for many purposes.

Machine No. 6 was also examined: the components were found to be in satisfactory alignment, but no position for testing cubes could be found which eliminated the systematic tilting of the kind shown in Fig. 2 (*d*). This machine differed in detail from machine No. 5, being less rigid laterally and it was felt that the lower rigidity was probably responsible for the somewhat anomalous platen movement already described. This suggests that a desirable feature of compression machines is that the frame should be of rigid construction, the columns being kept as short as possible. This is borne out by theoretical considerations of the stability of testing machines described by Chilver.[5]

Application of the Load

British Standard 1881 : 1952 requires that

Table III—*Summary of Results Obtained in Series 3 to 11*

Series No.	Size of cube (inches)	No. of cubes for each condition	First condition of test	Average crushing strength (pounds per square inch)	Second condition of test	Average crushing strength (pounds per square inch)	Approximate failing load (tons)
3	4	24	With proving ring	10,630	With solid cylinder	10,660	76
		12	With proving ring	4,230	With solid cylinder	4,200	30
4	4	16	Central on lower platen	9,560	Coaxial with ring	9,830	69
5	6	4	Central on lower platen	6,330	Coaxial with ring	7,160	108
6	4	6	Machine No. 5, ring re-centred	14,090	Machine No. 1	14,060	101
		6	Machine No. 5, ring re-centred	9,120	Machine No. 1	9,190	65
		6	Machine No. 5, ring re-centred	7,120	Machine No. 1	7,250	51
7	6	19	Machine No. 5, ring re-centred	6,940	Machine No. 1	7,130	113
8	4	12	Loading rate maintained (Machine No. 2)	3,340	Loading rate falling off (Machine No. 2)	3,170	23
		12	Loading rate maintained (Machine No. 1)	3,120	Loading rate falling off (Machine No. 1)	3,150	
9	4	8	Between ¼in plates	6,130	Without plates	6,020	98
10	4	18	Hydraulic platen	2,190	Spherical seating	2,320	16
		18	Hydraulic platen	4,920	Spherical seating	5,370	37
		18	Hydraulic platen	4,120	Spherical seating	4,400	30
		12	Hydraulic platen	9,560	Spherical seating	11,720	76
		6	Hydraulic platen	12,300	Spherical seating	12,580	89
		12	Hydraulic platen	6,780	Spherical seating	7,020	49
		12	Hydraulic platen	11,010	Spherical seating	12,280	83
11	6	12	Hydraulic platen	10,330	Spherical seating	11,140	173

when cubes are tested in compression the load shall be applied continuously at a rate of approximately 2000 lb per square inch per minute until the cube fails. In practice this requires that, as the cube approaches failure, the flow of hydraulic fluid to the cylinder of the machine must be increased. Even when this is done some machines are incapable of maintaining a constant rate of loading right up to the moment of failure. In experiments carried out by the Road Research Laboratory (Series 8) lower strengths have been recorded when the rate of loading is allowed to fall off in this way, but different machines behave differently in this respect. In particular, machine No. 2 showed a reduction of 5 per cent, while machine No. 1 did not show any significant change. Moreover, the reduction on machine No. 2 differed with different operators. When the load is allowed to fall off, the load/time curve will depend on the operation and on the characteristics of the machine. Since a variation in this will lead to variations in the observed strength, some standardisation is necessary and the only method which can be standardised at present is the use of a uniform rate of loading. It is therefore recommended that every effort should be made to maintain a constant rate of loading throughout the test by operating the control valve or other device to increase the flow of hydraulic fluid to the cylinder of the machine as the cube approaches failure. This is greatly facilitated in the machines with a dial indicator by the use of a pacing disc ; in the steelyard machines a constant rate of loading may be achieved with a motor-driven poise. With such devices some machines can maintain the standard rate to within a few seconds of failure. The rate of loading then rapidly falls and it is not expected that this would have any appreciable effect on the observed strength.

Alternatively a constant rate of strain could be applied to the specimen, but this also is difficult to achieve in practice, particularly in hydraulically operated machines. This method would correspond to a load/time curve having a maximum where the tangent was parallel to the time axis and this would provide a more clearly defined maximum than the system at present used. Since the compressive test is essentially a comparative test bearing little relation to the conditions met in engineering practice, either method would be acceptable and the choice would depend on the reproducibility obtained by the two systems and the ease of achieving them. There is no comparative information available on the question of reproducibility, but with most existing machines it is easier to approach the condition of a constant rate of increase of load.

Planeness of Platens

The planeness of the platens of the nine machines was examined using feeler gauges and a straightedge 6½in long. Machines Nos. 4 and 5 showed departures from planeness greater than the tolerance of 0·002in permitted in B.S. 1881 and amounting to 0·003in on one platen of each machine. One platen of machine No. 6 had a deviation from planeness of 0·002in, but the other machines were satisfactory in this respect. The bottom platens of machines Nos. 5 and 6 were convex while the other four platens of the three machines showing appreciable deviations were concave. The effect of these deviations has not been determined directly, but Dwyer[6] observed reductions in the crushing strength of 2in mortar cubes amounting to about 1 per cent and 3 per cent due to the use of platens which were concave and convex respectively to the extent of 0·002in in their width of 2in.

In examining machine No. 5, therefore, eight cubes (Series 9) were tested normally and eight were tested between two ¾in thick machined steel plates which would reduce, although not necessarily eliminate, the effect of the deviations from planeness. The cubes tested between the plates gave results higher than those tested without plates by only 2 per cent, a difference which cannot be considered significant. The standard deviation of the results, however, was only one-third of that obtained without the plates. It is thus clearly important to maintain the platens of a machine within the tolerance allowed by the British Standard if uniform results are to be obtained.

Freedom of Movement of Self-aligning Platens

Practically all compression testing machines are provided with a spherical seating, which enables the upper platen to adjust itself initially to the surface of a specimen whose bearing faces are not truly parallel. Little attention has been given, however, to the question of whether such seatings are able to move under load and thus maintain axial loading of a specimen in which the compressibility varies over its section. Tarrant[3] has shown that generally these seatings do not move freely under load, although with very precise finishing and the use of certain lubricants a relatively free platen can be obtained. He has also shown[4] that the use of a relatively freely moving platen can lead to a marked reduction in failing load and he gives a possible explanation of this.

Tarrant suggests that with a freely moving platen, which ensures axial loading, each half of the cube will receive its full share of the load and the specimen will fail when the average stress reaches the strength of the weaker half. With a platen that does not move so freely once it has assumed the plane of the specimen, greater stresses will be imposed in those parts of the cube which have the higher modulus of elasticity, and in general these are the stronger parts. The weaker parts will still fail first, but when they do the load on them plus the greater load on the stronger parts will together be greater than the load on the cube when using a freely moving platen, for which the total load is twice that on the weaker half.

An alternative form of self-aligning platen[7] has been commercially produced and tests at the Road Research Laboratory have shown that this is free to move under high loads, its resistance to movement being about one-tenth of that of a normal spherical seating. Comparative cube tests (Series 10 and 11) were made using the self-aligning platen and a spherical seating. In each batch of cubes tested the average results obtained with the hydraulic self-aligning platen was lower than that obtained with the spherical seating. The difference ranged from 2 per cent to 18 per cent. Further, the variation was greater with the hydraulic platen, the standard deviations being nearly twice those obtained with the spherical seating. Measurements of the movements of the platens during the tests showed that the hydraulic platen was permitting considerable differential movement, while the spherical seating generally moved very little. The lower average strengths and greater variation obtained with the freely moving platen would be expected from the explanation suggested by Tarrant.

Both these effects are believed to result from variations within individual cubes ; these variations are unavoidable characteristics of the present methods of making the cubes and are not normally of interest to the engineer. He is, however, concerned with obtaining reproducible results on nominally similar cubes, and although reproducibility in different laboratories has not been investigated it appears that on one machine the results are more reproducible if the platen, after adjusting itself initially to the shape of the specimen, remains fixed.

Conclusions and Recommendations

Although the tests described in this article have not provided complete solutions to the various problems which arise in testing concrete cubes, the following recommendations regarding machines can be made :—

(1) The testing machine should be provided with a spherical seating as required in British Standard No. 1881 : 1952. This should adapt itself initially to the shape of the specimen and thereafter should not move.

(2) Check that the ram of the machine, the positioning marks on the lower platen, the spherical seating or other self-aligning device and any load measuring device located above this are in good alignment. This can be done with sufficient accuracy using a fitter's square and straightedge and a steel rule marked with $^1/_{32}$in divisions. Observe whether there is any tendency for cubes to fail consistently on one side or the other and, if this is so, consider how the trouble can arise and take appropriate steps to correct it.

(3) Check the planeness of the platens regularly with straightedge and feeler gauges and have the platens reground when the departure from planeness approaches 0·002in. It is convenient to have a short straightedge made and kept for this purpose.

(4) During testing endeavour to maintain a constant rate of loading right up to the failure of the cube by operating the control valve or other device to increase the flow of hydraulic fluid to the cylinder of the machine as the specimen approaches failure. A pacing disc or similar device helps.

(5) If the results are suspect, (*a*) calibrate the machine to ensure compliance with grade A or B of B.S. 1610 : 1950[8] and (*b*) carry out comparative cube tests on the suspect machine and on another machine known to give reliable results. For this purpose it is recommended that twenty-four cubes should be used, twelve being tested on each machine. Care should be taken to ensure uniformity among the cubes, and if they are made from more than one batch of concrete equal numbers from any one batch should be tested on each machine. If it is necessary to transport the cubes some distance to one of the machines and they are, for example, packed in wet sand, the cubes for the other machine should receive exactly the same treatment.

Acknowledgments

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Nomogram for Steam Condenser Design

By J. P. DUNCAN, M.E., A.M.I.Mech.E., A.M.I.E. (Aust.).

IN 1934, H. J. Guy and E. V. Winstanley, published their paper entitled "Some Factors in the Design of Surface Condensing Plant" (Institution of Mechanical Engineers, 1934, Vol. 126, page 227). Based on a large number of studies of full-scale condensing plant, this paper considered carefully such practical problems as the pressure drop across the condenser, average fouling of tubes, rates of air leakage as well as the theoretical problems of condenser design which lend themselves to analysis. On this account the paper continues to provide designers with guidance in a field in which the literature is by no means extensive.

The accompanying nomogram is based on equations either stated or implied in Guy and Winstanley's paper, with an approximation for the value of the coefficient of heat transfer, the effect of which is discussed in Appendix I. With this modification, the variables involved can be mutually adjusted by reference to the nomogram, a procedure possessing advantages over the usual numerical solution.

The nomogram reproduced here is drawn for a two-flow condenser, a 25 per cent marginal factor on the coefficient of heat transfer K, and a zero pressure drop across the tubes on the steam side. This latter assumption implies that $t_3=t_4$ and may result in a calculated surface area 10 to 15 per cent less than actually required. In a design office it may be desirable to prepare similar nomograms for other than two flows or to vary the provision for fouling and pressure drop. For this reason details of construction of the nomogram are given in Appendix II. It may be noted that the variations mentioned affect Fig. 1 only; Fig. 2 is of perfectly general application to all cases.

Basis of Nomogram

Nomenclature.—The nomenclature agrees essentially with that of Guy and Winstanley but indices x, y and z have been introduced to simplify the writing of temperature differences. The variables may be conveniently grouped as follows:

Given Quantities:

- t_1=Temperature of the cooling water at inlet (deg. Fah.)
- t_3=Saturation temperature of the steam at entry to the condenser (deg. Fah.).
- t_4=Saturation temperature of steam at hot well (deg. Fah.).
- S=Pounds of steam condensed per hour (pounds per hour).
- i=Heat to be extracted from the steam per pound (B.Th.U. per pound).
- K=Ideal coefficient of heat transfer (B.Th.U. per deg. Fah. per square foot per hour).
- K_1=Reduced coefficient of heat transfer (B.Th.U. per deg. Fah., per square foot per hour).
- M=Utilisation factor on K ($M=K_1/K$).

Selected Quantities:

- d=Outside diameter of 18g tubes (0·048in wall thickness) (inches).
- d_1=Inside diameter of 18g tubes (0·048in wall thickness) (inches).
- l=Length of tubes (feet).
- V=Water velocity through tubes (feet per second).
- F=Number of flows.
- t_2=Circulating water outlet temperature (deg. Fah.).
- R=Water rate (ratio circulating water to condensate).

Dependent Quantities:

- t_m=Mean temperature different (Grashof) (deg. Fah.).
- $t=(t_1+t_2)/2$=Mean temperature of cooling water (deg. Fah.).
- $x=(t_3-t_1)$=Index of condenser size (deg. Fah.).
- $y=(t_3-t_2)$=Terminal temperature difference (deg. Fah.).
- $z=(t_2-t_1)=x-y$=temperature rise of cooling water (deg. Fah.).

Derived Quantities:

- Q=Quantity of circulating water per minute (gallons per minute).
- N=Number of tubes.
- Z=Area of cooling surface (square feet).

Design Equations.—Where $t_3=t_4$ by the assumption of zero pressure drop, the mean temperature difference between the steam and water sides of the condenser is given by the usual Grashof formula

$$t_m=(t_3-t_1)/\log_e\frac{t_3-t_1}{t_3-t_2}=(x-y)\log_e\frac{x}{y}=z/\log_e\frac{x}{y}$$

... Guy and Winstanley, 1934, equation (3) . . . . . (1)

The reduced coefficient of heat transfer based on Guy and Winstanley's equation (7) with an arbitrary marginal factor M is given by

$$K_1=M.K=M.650\left(\frac{V}{5}\right)^{\frac{1}{4}}\left(\frac{t}{100}\right)^{\frac{1}{4}} \quad . \ . \ . \quad (2)$$

For $M=0\cdot8$, $K_1=61\cdot7(V)^{\frac{1}{4}}(t_2+t_1)^{\frac{1}{4}}$ . . (2a)

For $M=0\cdot8$ and $(t_2-t_1)=13$ as an average case (see Appendix I)

$$K_1=61\cdot7(V)^{\frac{1}{4}}(2t+13)^{\frac{1}{4}} \quad . \ (2b)$$

The surface area Z required by the product $t_m \,.\, K_1$ and the specified rate of heat removal Si fixes the product of the number and length of tubes of given diameter through the relationships

$$Z=Si/t_mK_1=Nl\pi d/12 \quad . \ . \ . \ . \ . \quad (3)$$

The quantity of circulating water required per minute is found from

$$Q=Si/600(t_2-t_1)=Si/600z \quad . \ . \ . \quad (4)$$

and the water rate from

$$R=600Q/S=i/(t_2-t_1)=i/z \quad . \ . \ . \quad (4a)$$

Finally, the number of flows and the number of tubes and their diameter must be chosen to give a suitable water velocity according to the relationship

$$V=QF/2\cdot04d_1^2N$$

or, when $F=2$,

$$V_2=(Q/N)(1/1\cdot02d_1^2) \quad . \ . \ . \ . \ . \quad (5)$$

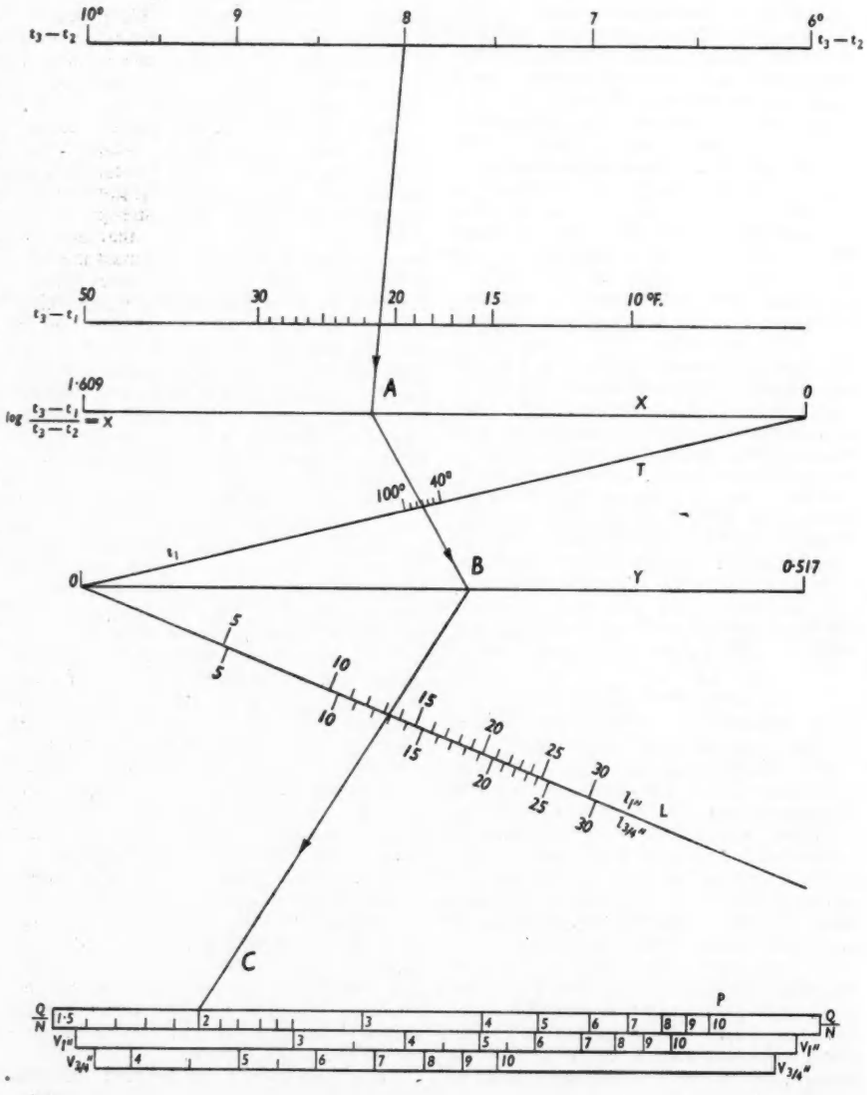

Fig. 1

The constant 1·02 implies fresh cooling water weighing approximately 62·5 lb per cubic foot.

For $d=1$in, $d_1=0{\cdot}904$in, $V=1{\cdot}205Q/N$
. . . . . (5*a*)

For $d=\frac{3}{4}$in, $d_1=0{\cdot}654$in, $V=2{\cdot}29Q/N$
. . . . . (5*b*)

Solution of Equations.—In order to prepare a nomogram for the simultaneous solution of equations (1) to (5) it is necessary to write these equations in a standard functional form suitable for graphical representation. The relationships involving temperatures and the velocity of the cooling water are represented on Fig. 1 and those involving the quantities of condensate and cooling water, the number of tubes and the cooling surface area on Fig. 2.

Fig. 1.—Equations (3) and (4) may be written as

$$t_m K_1 Z = Si = 600Q(t_2-t_1)$$

Substituting for K_1 and Z from equations (2*b*) and (3), respectively,

$$t_m \cdot 61{\cdot}7(V)^{\frac{1}{4}}(2t_1+13)^{\frac{1}{4}}(Nl\pi d/12) = Si = 600Q(t_2-t_1)$$

Substituting for t_m and V from equations (1) and (5), respectively,

$$\left\{(t_2-t_1)\log_e\frac{(t_3-t_1)}{(t_3-t_2)}\cdot 61{\cdot}7\,(Q/(N.1{\cdot}02d_1^2)^{\frac{1}{4}}\right\} \times(2t_1+13)^{\frac{1}{4}}(Nl\pi d/12) = Si = 600Q(t_2-t_1)$$
. . . . . (6)

For $d=\frac{3}{4}$in, 18g tube, equation (6) may be written as

$$(0{\cdot}0305l)(N/Q)^{\frac{1}{4}}(2t_1+13)^{\frac{1}{4}} = \left(\log_e\frac{t_3-t_1}{t_3-t_2}\right)$$
. . . . . (6*a*)

For $d=1$in, 18g tube, equation (6) may be written as

$$(0{\cdot}0295l)(N/Q)^{\frac{1}{4}}(2t_1+13)^{\frac{1}{4}} = \left(\log_e\frac{t_3-t_1}{t_3-t_2}\right)$$
. . . . . (6*b*)

Equations (6*a*) and (6*b*) have the general functional form

$$L\,.\,P\,.\,T = X$$

or

$$L\,.\,P = Y = \frac{X}{T}$$

where

$$L = C\,.\,l$$
$$P = (N/Q)^{\frac{1}{4}}$$
$$T = (2t_1+13)^{\frac{1}{4}}$$
$$X = \log_e\frac{(t_3-t_1)}{(t_3-t_2)}$$

By solving successively the three equations

$$X+\log_e(t_3-t_2) = \log(t_3-t_1) \quad . \quad . \quad (7)$$
$$X = Y\,.\,T \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (8)$$

and

$$Y = P\,.\,L \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (9)$$

equations (6*a*) and (6*b*) can be solved.

Equation (7) has been represented at the top of Fig. 1 as a nomogram of the so-called parallel scale type and equations (8) and (9), in the centre and at the bottom of Fig. 1, respectively, as nomograms of the "Z" type for representing products and quotients.

A typical solution of equation (6) is indicated by the vertical traverse across Fig. 1. For given values of t_3 and t_1 and either a selected or specified value of t_2, point A on the X scale is found. The numerical value is not usually of any interest so that no scale divisions are shown. Since the circulating water inlet temperature t_1 is usually beyond the designer's control, its value here, 70 deg., will fix the position on the T scale and hence give the point B on the Y scale. The numerical value of Y is of no special interest, hence scale divisions have been omitted. For a trial length of tube of specified diameter, for instance, 13½ft of 1in outside diameter tube or 12¾ft of ¾in outside diameter tube, the value of Q/N or V can be read at C. If the water velocity had been arbitrarily fixed, then the intersection of B, C on the L scale would give the tube length required.

Fig. 2.—This sheet is concerned primarily

TABLE I—*Details of Construction of Nomogram, Fig.* 2, *below*

1.	$R=\frac{Q}{S}\,.\,600$	Distance between scales	3in=k
	$RS=Q\,.\,600$	Length of scales	7in=h
	$\log R+\log S=\log Q+\log 600$	Ranges $f_1(u)=0{\cdot}301$	$m_1=23{\cdot}25$
	Equation type	$f_2(v)=1{\cdot}7$	$m_2=4{\cdot}12$
	$f_1(u)+f_2(v)=f_3(w)$	$m_3=\frac{m_1m_2}{m_1+m_2}=3{\cdot}5$	
2.	$\frac{N}{Q}=\left(\frac{N}{Q}\right)$	Distance between scales	3·5in=k
	$\log N-\log Q=\log\left(\frac{N}{Q}\right)$	Length of scales	7in=h
	Equation type		$m_1=3{\cdot}74$
	$f_1(u)-f_2(v)=f_3(w)$		$m_2=3{\cdot}5$
			$m_3=1{\cdot}81$
3.	$Z=Nl\pi d/12$	Distance between scales	3in=k
	$\log Z-\log N=\log l\pi+\log\frac{d}{12}$	Length of scales	7in=h
	Equation type		$m_1=3{\cdot}73$
	$f_1(u)-f_2(v)=f_3(w)+$constant (appropriate to tube diameter)		$m_2=9$
			$m_3=2{\cdot}635$

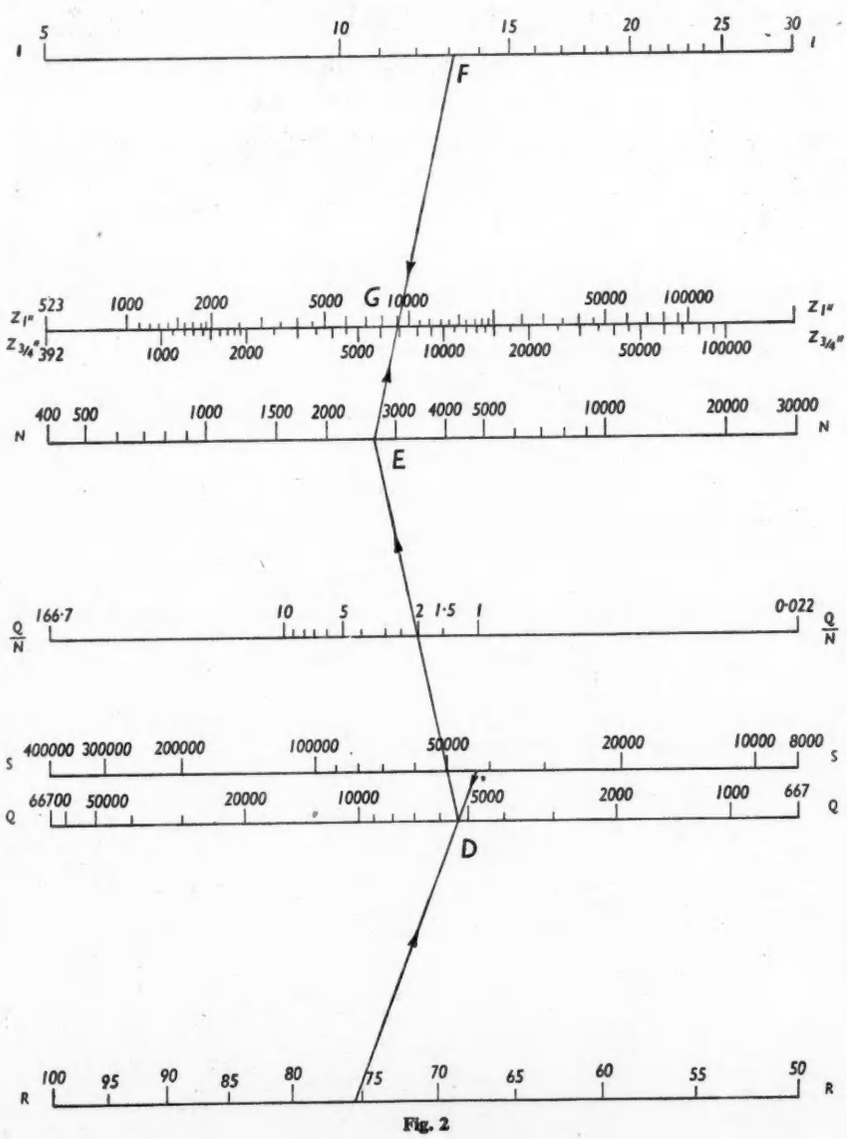

Fig. 2

TABLE II—*Details of Construction of Nomogram, Fig. 1**

1.	$X=\log_e \frac{t_3-t_1}{t_3-t_2}$	
	$X+\log_e(t_3-t_2)=\log_e(t_3-t_1)$	
	Equation type	
	$f_1(u)+f_2(v)=f_3(w)$	
	Distance between scales	$k=3\cdot5$in
	Length of scales	$h=7$in
	Ranges $f_1(u)$, 0 to 1·609, ...	$m_1=4\cdot35$
	$f_2(v)$, 1·792 to 2·303, ...	$m_2=13\cdot7$
	$\frac{m_1}{m_1+m_2}=0\cdot241$, $m_3=\frac{m_1m_2}{m_1+m_2}=3\cdot3$	
2.	$X=YT$	
	Distance along diagonal	$k=7\cdot2$in
	Length of both scales	$h=7$in
	Equation type	
	$f_1(u)=f_2(v).f_3(w)$	
	Ranges $f_1(u)$, 0 to 1·609, ...	$m_1=4\cdot35$
	$f_2(v)$, 0 to 0·517, ...	$m_2=13\cdot52$
	Distance along (w) scale	
	$=\frac{k.m_1.f_3(w)}{(m_1f_3(w)+m_3)}$	
3.	$Y=PL$	
	Distance along diagonal	$k=10\cdot95$
	Length of Y scale	$h=7$in
	Length of P scale	$h=10\cdot2$in
	Equation type	
	$f_1(u)=f_2(v)f_3(w)$	
	Ranges $f_1(u)$, 0 to 0·517, ...	$m_1=13\cdot52$
	$f_2(v)$, 0 to 0·8, ...	$m_2=12\cdot75$
	Distance along (w) scale	
	$=\frac{k.m_1f_3(w)}{(m_1f_3(w)+m_3)}$	

NOTE.—$f_3(w)$ has different values for the same value of tube-length according to diameter of tube and marginal factor, M, which affects the value of the coefficient of l in $L=f_3(w)$.

* See Marks, *Mechanical Engineers' Handbook*, 3rd edition, page 179.

APPENDIX I

In the evaluation of $(t_1+t_2)^{\frac{1}{2}}$ for specific practical temperature ranges, the expression reduces to $(2t_1+(t_2-t_1))^{\frac{1}{2}}$. Values of this expression are as follows :

t_1	$t_2-t_1=10$ deg.	$t_2-t_1=15$ deg.	$t_2-t_1=20$ deg.
40 deg.	3·08	3·128	3·16
100 deg.	3·81	3·83	3·86

Hence, by substituting $(2t_1+15)^{\frac{1}{2}}$ for $(t_1+t_2)^{\frac{1}{2}}$ the maximum percentage errors introduced over the range of t_2-t_1 considered above will be :

At cooling water temperature 40 deg. Fah. ±1·28 per cent
At cooling water temperature 100 deg. Fah. ±0·78 per cent

From these evaluations it is seen that at values of t_1 most frequently met (50 deg. to 80 deg. Fah.) the maximum percentage error introduced by the substitution will be about ±1 per cent at the limits of 10 deg. and 20 deg. for cooling water temperature rise. The above statements apply when t_2-t_1 is given the fixed value of 15 deg. In the nomogram t_2-t_1 has been given the fixed value of 13 deg. for purposes of this substitution only, as this figure agrees better with the average case.

with the number of tubes, N, in relation to the water rate R.

Equation (4*a*) may be written as

$$RS=600Q=600N\Big/\left(\frac{N}{Q}\right) \quad . \quad . \quad (4b)$$

and since

$$Z=Nl\pi d/12 \quad . \quad . \quad . \quad . \quad (2)$$

the following may be written :

$$\log R+\log S=\log Q+\log 600 \quad . \quad . \quad (10)$$

$$\log Q+\log\left(\frac{N}{Q}\right)=\log N \quad . \quad . \quad . \quad . \quad . \quad (11)$$

$$\log Z-\log N=\log l\pi+\log\left(\frac{d}{12}\right) \quad . \quad . \quad (12)$$

Each of equations (10) to (12) has the general form $A+B=C$ where A, B, C are functions of typical variables a, b, c, respectively. Each relationship may, therefore, be represented by parallel scale nomograms which may be arranged as in Fig. 2 to permit simultaneous graphical solution of the equations.

A traverse of three straight lines, as shown on Fig. 2, intercepts a set of values satisfying equations (10) to (12). For example, if S is specified as 43,000 lb per hour and R as 75·5, Q is found at D to be equal to 5400 gallons per minute, which may be checked from equation (4*a*). Having found from Fig. 1 that (Q/N) equals 2, N is found equal to 2600 at the point E. All the independent quantities have now been found. If, however, the length of tube found on Fig. 1 is now marked at F on Fig. 2, the intersection at G indicates the total surface area for tubes of either 1in or ¾in nominal outside diameter. In Fig. 1, tubes of 1in diameter require to be 13¼ft long. Fig. 2 shows that 2600 tubes would provide approximately 9050 square feet of condensing surface.

In each of Figs. 1 and 2 the effect of varying any one of a consistent set of variables can be rapidly assessed by modifications to the solution lines or traverses.

ACKNOWLEDGMENT

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Institution of Naval Architects

ANNUAL SPRING MEETING

No. IV—*(Concluded from page 605, April 19)*

THE first paper read on Friday afternoon, March 29, with Sir Charles Lillicrap, D.Sc., in the chair, was :—

CONDITIONS FOR UNSTABLE RUPTURING OF A WIDE PLATE

By G. M. BOYD

SYNOPSIS

One of the approaches to the research into the fractures in large steel structures has become known as "fracture mechanics." The present state of knowledge in fracture mechanics relates to the simple basic case of a wide thin plate under simple tension, with "fixed grip" end conditions, and is briefly reviewed. It is shown that as yet no wholly satisfactory quantitative theory is available. A qualitative hypothesis, based on the assumption that unstable fracturing settles down to a steady state, is proposed, which shows general qualitative agreement with experience. It explains some experimental observations and reveals a correlation between the Tipper and Robertson tests.

DISCUSSION

Dr. A. A. Wells : When Mr. Boyd proposes that there should be a steady state and proceeds to give it some definite properties, especially in relation to Fig. 6, one has to express disagreement on one particular point, and that is the value of the strain energy release dU/dc. In Fig. 6 it is suggested that this differs from the Griffith value and becomes steady when the crack has reached its uniform terminal velocity. I should like Mr. Boyd to define more closely the conditions of cracking to which he refers in this instance. If he is referring to a crack which is very large in comparison with the plate containing it, its postulated condition may be quite representative. On the other hand, if it is a crack running out in a steel plate and which is still unaffected by the edge conditions in that plate, I think a dimensional analysis will show that this sort of steady state cannot exist, that the value of the strain energy release rate must continue to rise as it does for the Griffith value.

The reason for this is that the stress, strain and displacement conditions surrounding that running crack are determined from the weak conditions of equilibrium and compatibility of strain, as in an elastic or partly plastic problem. If the conditions at the boundaries are fixed, one of these is an infinite boundary. If the ends of the plate are fixed, and the crack has a certain length, there must be certain contours around that crack of stress, strain and displacement which, from the dimensional point of view, must increase uniformly in all directions as the cracking increases. Thus the strain energy release rate must grow according to that asymptotic Griffith release line. But the kinetic energy must grow in a linear manner in the same way. If the kinetic energy is not allowed to grow, the crack must slow up and come to a stop.

Mr. J. M. Murray : The paper is admittedly speculative, but from the point of view of the layman it gives a convincing explanation of the mechanism of the propagation of brittle cracks. The more we know about that mechanism the more we are likely to know about the evaluation of the various criteria which have been put forward to explain the brittleness of a plate.

In Fig. 9 of the paper we see the effect of an initial notch. It appears to me that the initial value of the surface energy must be more or less independent of the length of the notch. If that is so it would follow that the length of the notch is not the preponderating factor in the initiation of brittle fracture. Fig. 10 coincides very closely as regards the dU/dc curve with the curves given by Dr. Wells for a similar case in his paper last year and it offers a reasonable explanation for the phenomenon which he finds so very frequently in shipbuilding ; that is the crack which starts under the influence of longitudinal welding stresses and extends only 2in or 3in.

We have done something to raise the level of the dW/dc curve in recent years in ship

steel, and we hope that the small fracture which extends for a few inches will not be so common. The whole problem seems to demand two approaches; one is the elimination as far as possible of the initial notch, and the second is to raise further the dW/dc curve.

Dr. W. D. Biggs: The condition for fracture initiation has been demonstrated to be associated with the application of stresses which create simulations of dislocation at certain borders within the crystal. In America, it has been shown that hard particles of macrostructure constituents can act in much the same way. We can expect that the initiation energy required by a hypothesis such as this one by Mr. Boyd will be very strongly affected by such factors as grain size, the relative strengths of the grain and the grain boundary, the type of macro constituent, the hardness and distribution of the macro constituent. I feel that a similar argument can be applied to the question of the propagation of a fracture. Dr. Wells has pointed out that the term about which we know the least is dW/dc, and this is the most important part of the argument, because the large amount of work which is involved in the propagation of an initial crack is far too often ignored.

Dr. R. Weck: It is evident that the approach of the metallurgist is quite different from that of the engineer. The paper by Mr. Boyd is the quintessence of the engineer's approach. It is an extremely plastic picture of fracture mechanics, understandable to an ordinary engineer such as myself. Metallurgists tend to consider this type of approach as being crude, and I wonder if they are not doing engineers an injustice. Metallurgists connected with the steel industry never tire of telling us that it would be quite impossible with the facilities available and in view of the never-ceasing cry for more production, to produce steel of better notch toughness at lower temperatures. So that the engineer is faced with the problem of having to use what he is given. But once he has made up his mind that he has to make the best use of what is produced, he can solve the problem only by trying to understand, not the metallurgy of it, but the mechanics, because he can only apply mechanical means by change in design or in fabrication methods.

I think, referring to Fig. 3, the increases in the dW/dc which Mr. Boyd indicated may be in consequence of the increase in temperature; but there may be an increase in band width. Very likely the increases in band width and in temperature are related, and it would be interesting if some attention could be paid to this particular question, as to whether, with increase in temperature, a wider and wider band of the material on each side of the fracture participates in the plastic deformation, which must invariably proceed.

Mr. G. Coats: Speaking as a physicist, I shall be able to disagree with both the metallurgists and the engineers. I was interested to hear the discussion on the temperature dependence attributed to dW/dc, for I consider this to be an extremely important item for future research. When I looked into this a little more deeply, the conclusion I came to was that the dW/dc is not really known to be temperature dependent. Dr. Weck tended to the view that what we are really measuring is the width of the band and the band formation. Nevertheless, there is still a temperature dependence in steel.

Surely the influence of the speed does not have a direct bearing on the mechanism in this paper. The only way is to consider whether a rough notch or a sharp notch alters appreciably the figures given in the middle part of the paper.

The last paper presented at the spring meetings was:

SHIP HULL PRESSURE MEASUREMENTS

By N. Hogben, B.Sc., Ph.D.

Synopsis

The pressure measuring project described was the major part of the programme undertaken by the writer as holder of the "1851 Exhibition Postgraduate Research Scholarship," and carried out in the Department of Naval Architecture, King's College, Newcastle upon Tyne, in the University of Durham.

After briefly discussing the importance of pressure measurement in relation to the study of ship resistance, this paper gives an account of the experimental method and of the analysis and interpretation of the results.

The model *KC*1 made for the experiments had the form of No. 1 in Professor Lindblad's Series and had length on water line 100in. Pressures were measured by means of an open-topped water-manometer at seventy-six positions at nine speeds in the range $V/\sqrt{L}=0{\cdot}8$ to $1{\cdot}1$. The readings were all cross-plotted against speed and interpolated to give the results shown at the seven speeds $V/\sqrt{L}=0{\cdot}80$, $0{\cdot}85$, $0{\cdot}90$ . . . $1{\cdot}1$. Wave profiles determined photographically were used to assist in extrapolating the pressure measurements up to the free surface.

The results are summarised by Figs. 1 and 2 and Tables I and II, which present pictures of the pressure distribution over the surface of the model at each of the seven chosen speeds, and a curve of pressure resistance to a base of $V/\sqrt{L}$ obtained by integration of the pressure forces.

Discussion

Mr. W. C. S. Wigley: Various methods have been proposed for correcting the wave resistance as calculated at low speeds. Generally it has been assumed that oscillation at these speeds would occur in a perfect fluid, but does not occur actually because of viscosity. But there are two views about that and I hold the view that this oscillation is probably a perfect fluid effect and that it is cancelled by the viscosity. It is well known as a fact that you do get oscillation.

Dr. R. S. Guilloton (contribution translated and presented by Mr. Wigley): In my opinion Dr. Hogben might have found room for a critical examination of some important work by Captain H. F. Eggert, which appeared in two papers before the Society of Naval Architects and Marine Engineers in New York, the first in 1935. It seems that Eggert and his critics arrived at no definite conclusions, and it is to be feared that the same fate will be met by the present paper, unless it involves some novelty in comparison with the work of Eggert. A critical examination as suggested would have for its object to underline the novelties in the present paper, and the developments which might be expected from them. In fact, the resistance to motion calculated from the pressures measured by Eggert is, at low speeds, higher than the residuary resistance evaluated by the usual methods, while Dr. Hogben finds a contrary result.

The author remarks that the results of the wave calculations differ from the resistances derived from the integration of pressures. I am convinced that the linearised potential does not give practically useful results for ships. Such calculations will be useless until a practical method of correction has been published to include the terms of order above the first.

The author gives wave profiles extrapolated from pressures. One would like to know exactly how these waves have been obtained.

I would like to draw attention to a point which seems to me to be fundamental. For a long time there has been a taboo on criticism of experiment, while theoretical ideas have suffered from a degree of scorn. But one should have the courage to state that there is one idea which is fundamental in the study of hulls, and that is that the hull is moving through a fluid without viscosity, subject to Froude's law of similarity. But experiment does show that this assumption is right and that there is in fact a part of the resistance of ships which follows approximately this law of similarity excluding the viscosity. Besides, this can be explained by the fact that in the operation of a ship the water can be considered as a perfect fluid, except for a small volume in the immediate neighbourhood of the hull.

Although this idea is difficult to define physically, yet when we speak of resistance normal to the hull, or of wave resistance, or even of residuary resistance, it is this resistance in a fluid without viscosity which we mean.

From this consideration it seems risky to determine this resistance as the author has, by measurements made on the hull, that is, precisely in that small volume of fluid which is not perfect. I may be allowed to recall that in 1952, in my paper to the Institution of Naval Architects, "A Note on the Experimental Determination of Wave Resistances," I proposed the surface wave as a basis for this calculation. The surface wave shows the advantage of being the resultant of motions existing in the whole or that part of the fluid which can be considered as without viscosity and is directly controlled by the boundary condition at the free surface which gives rise to Froude's law of similarity. It is constituted from a series of manometric heights analogous to those measured by Dr. Hogben. There are some improvements to be made in its interpretation, particularly by the use of the functions T given in my paper before the Association Technique Maritime et Aeronautique in 1956. When account is taken of these points it does not seem that there is any more theoretical complication in passing from the surface wave to the resistance than in passing from the manometric heights measured by Dr. Hogben to the resistance, for it seems that the theory of the pitot tube is neither simple nor certain.

An important advantage in the use of the surface wave is that the calculations are made from differences of pressure, while the measurements by Dr. Hogben depend on absolute pressures.

Mr. H. Lackenby: The British Shipbuilding Research Association, in conjunction with the National Physical Laboratory, has carried out somewhat similar work for a considerable time. We were concerned with the interdependence of wavemaking and skin friction resistance, but the aspect has been broadened, and the work now covers the physical nature of resistance in general. The work is done at the N.P.L. and involves special problems, with mathematical models in a tank.

Where I think Dr. Hogben has left something out is that in measuring the pressure on the model he has not separated out the wavemaking resistance. The measured resistance does include resistance of viscous origin; in other words, the resistance of viscous origin and of gravitational origin has not been completely separated. If Dr. Hogben had taken the pitot traverse with the total head behind the model he could have determined the total resistance of viscous origin. He would have real wavemaking in the presence of viscosity, pressure resistance of viscous origin and the true skin friction.

In the B.S.R.A. and N.P.L. work we are doing this total head and wake traverse in addition to the pressure plotting which Dr. Hogben has done.

Metallurgical Topics

High-Temperature Oxidation of Carbide Alloys

SOME years ago, W. Kinna and O. Rüdiger[1] investigated the scaling mechanism of a carbide alloy (82 per cent titanium carbide, 18 per cent cobalt). In the range 600 deg. to 1000 deg. Cent. the rate of oxidation followed a parabolic law. Two oxide layers were found, an outer one of CoO or Co_3O_4 and an inner one of TiO_2 with interspersed metallic cobalt. Above 1000 deg. Cent. cobalt titanate, $CoTiO_3$, was also detected. The structure of the scale was affected by the relative increase in volume on oxidation of the cobalt and the titanium carbide.

In continuation of this work, J. Hinnüber, O. Rüdiger and W. Kinna[2] have investigated the influence on rate of oxidation of additions of tungsten, chromium and tantalum carbides to the titanium carbide-cobalt alloys. A hard-metal alloy containing titanium carbide 80, cobalt 20, per cent, served as the basis, and to this was added (with corresponding variations in the titanium carbide content) 1 to 60 per cent tungsten carbide (WC), 1 to 20 per cent chromium carbide (Cr_3C_2) or 1 to 40 per cent tantalum or tantalum-niobium carbide (TaC or (Ta, Nb) C). The amount of scaling was measured, and the oxide layer was studied with the aid of the optical and the electron microscope, and by X-ray methods. Fig. 1 shows the influence of additions

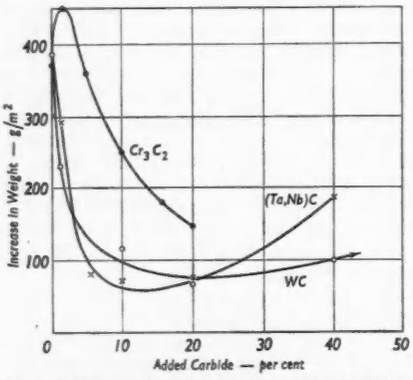

Fig. 1—Influence of carbide additions on the oxidation of titanium carbide-cobalt alloy, heated for twenty-five hours at 1000 deg. Cent.

of WC, Cr_3C_2 and (Ta, Nb)C on the oxidation undergone by alloys containing 20 per cent cobalt, $(80-x)$ per cent TiO_2 and x per cent of the added carbide after being heated at 1000 deg. Cent. in air for twenty-five hours. The rate of oxidation at 1000 deg. Cent. in all cases followed a parabolic law, slight deviation from this being shown only by the alloy containing 20 Co, 20 TiC and 60 WC.

EFFECT OF TUNGSTEN CARBIDE

The rate of oxidation fell with increasing amounts of tungsten carbide up to 20 per cent and then rose again. As in the pure TiC–Co alloy, the scale of the alloys with tungsten carbide additions consisted of two layers, the outer one of CoO and the inner one of TiO_2 with interspersed metallic cobalt. With low tungsten carbide contents, the WO_3 formed is dissolved in the TiO_2 and, because of the higher valency of tungsten ions, the ionic diffusion diminishes and the resistance to oxidation improves ; hence the rapid fall in the amount of oxidation of the alloys containing a few per cent of WC. With increasing content of tungsten carbide (upwards of 10 per cent) the compounds $CoTiO_3$, $CoWO_4$ and Co_2TiO_4 were found in the inner scale and the amount of interspersed metallic cobalt diminished. On account of the many phase boundaries in the oxide layer these alloys are still highly resistant to oxidation, as shown in Fig. 1. In the alloys containing 40 and 60 per cent of tungsten carbide, however, free WO_3 is formed in the oxide layer and is not removed either by solution or as a complex oxide. The 60 per cent alloy possesses no outer layer of cobalt oxide. Both these effects lead to a deterioration in resistance to oxidation and finally to spalling and break-up of the scale.

EFFECT OF CHROMIUM CARBIDE

Small additions of Cr_3C_2 to the TiC–Co alloy increase the rate of oxidation, whilst higher chromium carbide content steadily improves the resistance to oxidation. The first effect arises from the solution of Cr_2O_3 in the TiO_2 of the inner layer of scale, since this, on account of the smaller valency of the chromium ion, increases ionic diffusion. The favourable effect of higher Cr_3C_2 content is due to the formation of free Cr_2O_3 in the oxide layer. At temperatures of 500 deg. to 600 deg. Cent. porosity of the scale is very unfavourable to the oxidation resistance of alloys containing Cr_3C_2, but at 1000 deg. Cent. the oxide layer produced covers over the existing pores and makes the specimen resistant to subsequent oxidation at lower temperatures.

It may be observed that the behaviour of the Cr_3C_2–TiC–Co alloys is similar to that of the chromium-cobalt alloys investigated by Phalnikar, Evans and Baldwin[3] in showing more rapid scaling at first, followed by improved resistance to oxidation as the chromium content is increased. In both cases the best resistance to scaling was associated with a scale consisting predominantly of Cr_2O_3. The scale formed on the metallic alloys containing more than 20 per cent of chromium was found by Phalnikar, Evans and Baldwin to spall badly on cooling to atmospheric temperature, thus seriously reducing their value for components which may undergo cyclic changes of temperature. The carbide alloys investigated by Hinnüber, Rüdiger and Kinna extended only to 20 per cent chromium carbide, at which composition the resistance to scaling was still improving with rise in the Cr_3C_2 content, and it would be interesting to have information about the behaviour of carbide alloys with more than 20 per cent of chromium carbide.

EFFECT OF TANTALUM CARBIDE

The addition of even a small amount of tantalum-niobium carbide to titanium-carbide-cobalt alloys diminishes the rate of oxidation considerably. There is no free cobalt in the oxide layer of alloys with 5 per cent (Ta,Nb)C and no outer layer of cobalt oxide when the (Ta,Nb)C content reaches 10 per cent. No tantalum or niobium oxide is found in the scale, which, with 20 or 40 per cent of (Ta,Nb)C, has a lattice of the rutile type with increasing lattice constants showing that the oxides of cobalt, tantalum and niobium are dissolved in the TiO_2. The reduction in resistance to oxidation shown by the alloys containing a high (Ta,Nb)C content may be due to the joint effect of Ta, Nb and bivalent Co in the rutile lattice on the diffusion of oxygen.

APPLICATION TO HARD-METAL TOOLS

The knowledge that the oxidation resistance of both the cementing metal and the carbide phase is improved by tantalum-niobium carbide additions may be of importance not only for high-temperature alloys, but also for (Ta,Nb)C-containing tungsten carbide-titanium carbide-cobalt cutting tools. Wear of these carbide tools is less in an inert atmosphere (nitrogen) than in air, and is much greater in oxygen. The increase in resistance to oxidation of the cobalt and the carbide phase by small additions of tantalum carbide is evident in an improvement in tool life, as is confirmed by workshop tests.

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[2] *Technische Mitteilungen Krupp*, November, 1956, page 140.
[3] *Journal of the Electrochemical Society*, August, 1956, page 429 ; THE ENGINEER, September 28, 1956, page 436.

Chromium-Manganese-Nickel Heat-Resisting Steels

SHORTAGE of nickel during the war led to the use of austenitic chromium-manganese steels for heat-resisting purposes. It was not found possible to obtain a completely ferrite-free austenitic structure in chromium-manganese steels with more than 15 per cent of chromium. Prolonged heating at 500 deg. to 800 deg. Cent. produced brittleness in chromium-manganese steels containing 13 per cent or more of chromium. This embrittlement was attributable to separation of the sigma phase which occurs on long annealing in 33 per cent chromium steel at 800 deg. Cent., in 26 per cent chromium steel at 700 deg. Cent., and in 18 per cent chromium steel at 600 deg. Cent. In chromium-nickel steels the limit for the appearance of the sigma phase is displaced to a higher chromium content. Manganese in chromium-containing steels is a much weaker austenite-forming element than nickel and, in contrast to nickel which represses the formation of the sigma phase, manganese favours the separation of sigma and accelerates its precipitation.

The structure, hardness, impact and magnetic saturation values of chromium-manganese steels containing nickel have been investigated by H. Krainer.* Tests were carried out on forged

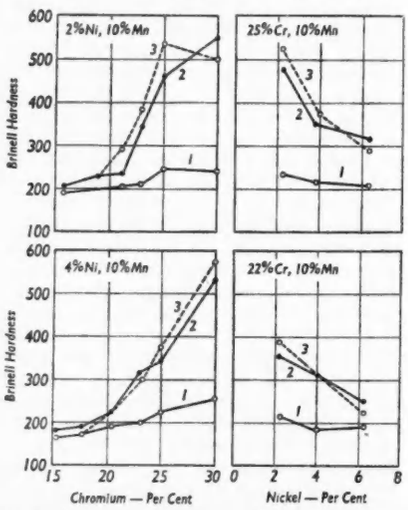


Fig. 1—Influence of chromium and nickel content on the hardness of chromium-manganese-nickel steels with 10 per cent manganese after the following heat treatments : (1) 1200 deg. Cent./water ; (2) 1200 deg. Cent./water+100 hours 800 deg. Cent. ; (3) 1200 deg. Cent./water+1000 hours 650 deg. Cent. (Krainer)

specimens of 120 low-carbon chromium-manganese-nickel steels with 10–30 per cent chromium, 2–20 per cent manganese, and 2, 4 or 6 per cent of nickel in three conditions of heat-treatment ; viz. quenched in water from 1200 deg. Cent., quenched in water from 1200 deg. Cent. and heated for 1000 hours at 650 deg. Cent., and quenched in water from 1200 deg. Cent. and heated for 100 hours at 800 deg. Cent. The presence of the sigma phase was reflected in the hardness and impact value of the specimens. Fig. 1 shows the influence of chromium and nickel content on the hardness of the steels containing 10 per cent of manganese. The steels with a hardness of 200 or less had impact values of about 25 mkg per square centimetre. The great increase in hardness of the high chromium alloys, caused by the separation of the sigma phase in the reheated specimens, was accompanied by a marked fall in impact value tending towards extreme brittleness with impact values less than 0·5 mkg per square centimetre in steels

* *Archiv für das Eisenhüttenwesen*, February, 1957, page 81.

with high chromium after prolonged heating at 650 deg. or 800 deg. Cent.

An advantage of the chromium-manganese steels is their good creep strength which, at 750 deg. Cent., is said to be markedly better than that of a chromium-nickel steel with chromium 19, nickel 9 per cent. On the other hand, their resistance to scaling is not so good. Attempts to improve scaling resistance by additions of silicon or aluminium met with no success because both these elements favoured the separation of the sigma phase, necessitating a further reduction in the chromium content. Higher nitrogen content tended to retain austenite and suppress the precipitation of sigma ; the creep strength also was improved, especially by the simultaneous addition of molybdenum or vanadium, but the limits imposed by scaling resistance were not extended.†

In steels containing ferrite and austenite the sigma phase separates in the ferrite : in nickel-free chromium-manganese steels, after prolonged heating, it appears when chromium exceeds 13 per cent. By the addition of nickel this limit is raised by about 6 per cent so that the recommended modification of the chromium-manganese steel, viz. one containing chromium 18, manganese 5 to 8, nickel 6 per cent, possesses (as shown by the data in the accompanying table) a stable austenitic structure which is not embrittled by prolonged heating at 650–800 deg. Cent.

Properties of a Chromium-Manganese-Nickel Steel

Steel No. 94. Composition, per cent

Carbon	Silicon	Manganese	Chromium	Nickel
0·06	0·49	5·2	18·0	6·3

	—	W.q. 1200 deg. Cent.	W.q. 1200 deg. Cent. 1000 hour, 650 deg. Cent.	W.q. 1200 deg. Cent. 100 hour. 800 deg. Cent.
Brinell hardness		170	166	156
Impact value, mkg per square centimetre		22·4	22·0	30·4
Magnetic saturation, $4\pi J_s$ ...		0	0	0

Low-Temperature Brittleness

In the Edward de Mille Campbell Memorial Lecture delivered at the annual meeting of the American Society for Metals in October, 1956, Professor C. S. Barrett of the University of Chicago dealt with the subject of low-temperature brittleness.* He first dealt with researches arising from the wartime outbreak of failures of welded merchant ships and tankers. Even with perfect welds and good design, notches producing stress concentrations cannot be avoided throughout the whole life of a ship, so that it is necessary to make use of material that is crack-resistant, even in the presence of notches, under the conditions of service. A crack will propagate across a mild steel plate at a stress of about 5½ tons per square inch when the yield point of the steel is 18 tons per square inch ; and in low-carbon steel plates the stress at which a crack is extended may be much lower than this. To design for such stresses is obviously impracticable. The only solution is to lower the temperature of transition from tough to brittle fracture so that the steel remains tough at service temperatures. The relative value of different methods of defining and determining transition temperature are discussed. The correlation of test results and service failures has indicated compositions and steel-making practices which can provide satisfactory performance in various thickness ranges.

Fundamental Researches

On the fundamental side the number of questions needing further investigation is very large. Reference is made to researches dealing with low-temperature transformations, phase diagrams at low temperatures and the effect of low temperatures on the mechanical properties of metals. The part played by crystal imperfections in each of these fields is pointed out, a distinction being made between *point defects* caused by vacant atomic sites or by interstitial atoms, *line defects* or dislocations, *surface defects* including " arrays of dislocations acting in unison " and thin microcracks, and *volume defects* which may be displacement spikes or rounded cavities. No one set of defects is responsible for low-temperature brittlenesss. This may be caused by any factor which raises the level of local stresses at the cleavage planes.

Effect of High-Energy Radiation

Fundamental questions awaiting further investigation also include the permanent changes induced in metals by bombardment with high-energy particles. Irradiation by neutrons, electrons or other nuclear particles causes atoms to be knocked out of their lattice positions and creates various lattice defects. Such effects of high-energy radiation are sometimes considered to be of only theoretical importance. It was found, however, that irradiation of a pressure-vessel steel with $2{\cdot}5\times10^{19}$ neutrons per square centimetre raises its transition temperature from −30 deg. to +50 deg. Cent. While there are very few parts of a nuclear power plant that are hit by anywhere near this amount of radiation, it is obvious that any steel or other metal used near the core of a reactor must be chosen with this radiation-embrittlement danger kept closely in mind.

The complete lecture is to be published in the 1957 volume of the *Transactions of the American Society for Metals.*

† *Archiv für das Eisenhüttenwesen*, 1941–42, Vol. 15, pages 467 and 514.

* Abridged report in *Metal Progress*, December 1956, page 68.

Effect of Environment on Creep-Rupture Properties

The high-temperature properties of alloys are influenced by the atmosphere in which they are tested or the environment in which they operate. In comparison with behaviour in an inert atmosphere, there may be an increase or a decrease in creep resistance and rupture life. An investigation has been carried out by P. Shahinian* to determine the creep-rupture behaviour of six alloys in various atmospheres (air, oxygen, nitrogen, helium and vacuum). The alloys were : 1·3 per cent chromium-molybdenum steel, oil-hardened and tempered ; 12 per cent chromium-vanadium steel, normalised ; 19–9 chromium-nickel steel, water quenched ; two super-alloys containing cobalt, chromium and nickel in percentage 43–20–20 and 20–20–20, respectively, with additions of molybdenum, niobium and tungsten, solution treated, quenched and aged ; and Inconel X, solution treated, air cooled and aged. Creep-rupture tests were made on unnotched and on notched specimens for times up to 500 hours at temperatures from 593 deg. to 815 deg. Cent.

The minimum creep rate was generally lowest for the alloys in air. The rupture life was longer in air than in oxygen, nitrogen, helium or vacuum. In general, oxidising atmospheres resulted in longer rupture lives than the inert atmospheres. The presence of a notch in the alloys of relatively low ductility (Inconel X and the 43 per cent cobalt alloy) greatly increased their susceptibility to the influence of environment. Inconel X at 815 deg. Cent. and 11·2 tons per square inch was notch strengthened in air and oxygen atmospheres, but was notch weakened in nitrogen or a vacuum.

The influence of environment on properties may arise from various single effects or combinations of these. Surface films may inhibit the generation and/or migration of dislocations. An oxide film may mechanically strengthen the bulk material, and internal oxidation may also have a strengthening effect. Oxygen penetration into grain boundaries may occur and result in improved creep resistance, which might be markedly increased by only a slight strengthening of the boundaries. The test data suggested that there might be an optimum amount of oxygen required in the test atmosphere for the highest creep and rupture strengths.

The greater atmosphere sensitivity of notched over unnotched specimens indicated that blunting of cracks by oxidation, which would tend to retard crack propagation, may also be a factor in prolonging specimen life.

*American Society for Metals, 1956 Preprint, No. 34.

Impact Tests on Leaded Steels

It is well recognised that the tensile strength of steels to which a small quantity of lead has been added to improve machinability is similar, both in the longitudinal and transverse directions, to that of the same steel without lead, heat-treated in the same way. The results of notched-bar impact tests are not so consistent. Impact characteristics were the particular concern of A. P. Weaver[1] in a recent paper on leaded and non-leaded steels. In tests on 0·5 per cent carbon steel, coarse grain and fine grain, and on steel containing carbon 0·45 and manganese 1·5 per cent from three pairs of ingots, one of each pair including 0·2 to 0·3 per cent of lead, he found, as might be expected, no significant difference in Brinell hardness and longitudinal tensile properties between the leaded and the non-leaded materials, whether hot-rolled, normalised or quenched and tempered. At room temperature the lead-bearing steel, in nearly every instance, had the higher impact value, even though the difference amounted to only 1ft-lb or 2ft-lb in the fine grain steel. The transition temperature of the coarse grain steel containing lead was 15 deg. to 50 deg. Fah. lower than that of the same steel without lead. The lowering of the transition temperature was attributed to slight grain refinement due to the lead. In the fine grain steel the difference in transition temperatures of the steels with and without lead varied from −10 deg. to 15 deg. Fah. A significant feature, however, was that the impact value/temperature curves crossed so that above the transition range the lead-free steel always showed the higher impact energy. Whether the lead-free or the lead-treated steel shows the higher impact value seems, therefore, to depend on the temperature of the test in relation to the transition range, which, in the case of the steels studied, extended well above room temperature.

In steels with a low transition temperature it would appear likely that the lead-treated steel would have a lower impact value than the lead-free steel at room temperature. This suggestion is borne out by the fact that out of fourteen typical pairs of tests on heat-treated, lead-free and lead-treated alloy steels, published by Messrs. Samuel Fox and Co.[2] some years ago, there was only one instance in which the lead-treated steel had a higher impact value than the corresponding lead-free steel.

References

[1] *Transactions, American Society for Metals*, 1956, Vol. 49, Preprint No. 22.
[2] " Some Notes on Alloy Steels Containing Lead."

New Nodular Iron Process

The value of nodular graphite in cast iron has long been recognised in malleable iron made by annealing white iron castings, and more recently in cast iron treated with certain addition agents such as cerium in the form of mischmetal or magnesium in the form of an alloy with nickel.

A process of making nodular cast iron which is less expensive and leaves a minimum amount of residual magnesium and no other added element in the final castings has been suggested, after a considerable amount of experimental work, by H. K. Ihrig.* In this process use is made of a mixture of sodium and magnesium chlorides reduced with calcium-silicon (30 per cent calcium). The molten base iron was poured on to this mixture and, after the reaction had taken place, the slag was skimmed off and the molten metal poured into moulds. The process was for several months in commercial operation in the foundry. Approximately 1400 tons of various castings, ranging in size from a few pounds to over 5 tons, have been successfully produced. The castings possessed the characteristic high strength and good ductility of nodular graphite irons. Elongation on 2in was seldom less than 10 per cent. The machinability as-cast was also very good. The magnesium content was below 0·03 per cent and no alloying elements are introduced into the melt, hence return scrap may be used in any amount. The process is put forward as an improved method of producing good quality ductile iron without annealing and without introducing other elements with the nodulising addition.

*American Society for Metals, 1956 Preprint, No. 7.

LETTERS AND LITERATURE

Letters to the Editor

(We do not hold ourselves responsible for the opinions of our correspondents)

HIGH-VOLTAGE SURGE GENERATOR

SIR,—We wish to refer to the report on page 503 in your March 29 issue on the 2,400,000V, 104kW-seconds surge generator manufactured by Etablissements E. Haefely et Cie., Basle, in which it is stated that this plant in service at Jeumont is the most powerful equipment at present in use in Europe.

May we point out that we have installed in our transformer factory at Hollinwood, Lancashire, an impulse generator of 285kW-seconds stored energy and a peak voltage of 4,000,000V. The corresponding figures of the impulse generator at Jeumont are 104kW-seconds and 2,400,000V. The Ferranti generator can also be charged either positively or negatively up to 220kV d.c. We would also bring to your notice that we are at present commissioning an impulse generator of similar design to the 4,000,000V generator for the British Electrical and Allied Industries Research Association at Leatherhead, which is itself more powerful than the impulse generator at Jeumont with an output of 120kW-seconds and a peak voltage of 2,800,000V. In addition, a Ferranti impulse generator having an output of 120kW-seconds and a peak voltage of 2,400,000V will shortly be erected at the works of Enfield Cables, Ltd.

A. HILL,
Publicity Department.
Ferranti, Ltd., Hollinwood,
Lancashire,
April 17, 1957.

[So, not by any means for the first time, we have it brought home to us that Britain is a part of Europe. It is very easy for us, living on this island, to forget it and the inhabitants of the Continent sometimes forget it too ! In stating that the plant is the most powerful in Europe, Etablissements E. Haefely et Cie., no doubt had the Continent in mind. We in printing the statement made the same mistake.—Ed. THE E.]

LAMINAR FREE CONVECTION : A NEW FORMULA

SIR,—In a paper presented recently to the Ninth International Congress of Applied Mechanics, new theoretical work was reported on heat transfer by laminar free convection from an isothermal vertical plane surface.[1] The purpose of this note is to draw attention to the fact that it is possible thence to derive a useful approximate formula which combines simplicity with a very reasonable degree of accuracy.

Dimensional analysis shows that :—

$$Nu = \Phi\{Gr, Pr\}$$

where

Nu is the Nusselt number, $\alpha L/k$,
Gr is the Grashof number, $\beta g \theta L^3 \rho^2/\eta^2$,
Pr is the Prandtl number, $\eta c/k$,
L is height of plane,
α is heat transfer coefficient ($\alpha = \dot{Q}''/\theta$),
k is thermal conductivity,
β is coefficient of expansion,
g is (local) acceleration of free fall,
θ is temperature excess,
ρ is density,
η is viscosity,
c is specific heat capacity.

It is further established that for laminar flow of boundary layer type we have :—

$$Nu = C(Ra)^{\frac{1}{4}}$$

where C depends on Prandtl number and Ra is the Rayleigh number, $Gr.Pr$.

In the paper mentioned a solution was presented for the limiting cases of zero and infinite values of the Prandtl number. The familiar ordinary differential equations,[2] to which Schmidt and Beckmann's boundary layer equations may be reduced by Pohlhausen's method, were further transformed in such a manner as to exhibit clearly the nature of their solutions for the two extreme cases. Numerical solutions of these equations were reported. The solutions imply :—

$$Nu = 0{\cdot}800\,544\ (Gr.Pr^2)^{\frac{1}{4}} \text{ for } Pr \to 0,$$
$$Nu = 0{\cdot}670\,327\ (Gr.Pr)^{\frac{1}{4}} \text{ for } Pr \to \infty.$$

It was further shown that these results, together with Ostrach's results[3] for the intermediate values of Pr ranging from 0·01 to 1000, could be expressed within about a part in a thousand by the interpolation formula

$$C^4 = Pr/(2{\cdot}434\,78 + 4{\cdot}884\,Pr^{\frac{1}{2}} + 4{\cdot}952\,83\,Pr).$$

With but slight reduction in accuracy this may be arranged to give

$$\boxed{(Nu^4/Ra) = C^4 = 2Pr/5(1 + 2Pr^{\frac{1}{2}} + 2Pr).}$$

This simple formula gives values of Nu within 1 per cent of the true values over the whole range of Pr. This is recommended for use in practical calculations provided $Nu > 6$ and $Ra < 2000\,000\,000$.

E. J. LE FEVRE
Mechanical Engineering Research
Laboratory, East Kilbride,
March 27, 1957.

REFERENCES

[1] Le Fevre, E. J., "Laminar Free Convection from a Vertical Plane Surface." To appear in the *Proceedings* of the Ninth International Congress of Applied Mechanics. 1956.
[2] Schmidt, E., and Beckmann, W., Techn. Mech. u. Thermodynamik, I, 341–391, 1930.
[3] Ostrach, S., N.A.C.A., T.N. 2635, 1952.

LET'S FORGET THE CYCLOID TOOTH

SIR,—I have read Professor Tuplin's article "Let's Forget the Cycloid Tooth," in THE ENGINEER, December 14, 1956, and his letter in THE ENGINEER of April 12, 1957.

Years ago, I said to the late Mr. Sykes, "An involute gear has no fixed pitch circle." He laughed and said, "I know, but some people won't believe it."

What the Professor says is, of course, quite correct, but how would he start designing a system of involute gears without assuming an imaginary pitch or rolling circle ?

A 10 D.P. gear of twenty teeth has a normal rolling or pitch circle of 2in diameter.

If one wants it to work with a similar gear at 20 deg. pressure angle, then $2X \cos 20$ deg. = base circle diameter. This, divided by 20 = base circle pitch, which is the one thing that never changes in 20 deg. 10 D.P. gears.

How would the Professor get his base circle diameter and base circle pitch ?

Three 10 D.P. gears, with, say, twenty teeth each, may be cut with the same cutter : normal, abnormal, and subnormal. They will have different outside diameters and varying rolling circles, but they will mate together because their base circles are the same diameter, and therefore their base circle pitches are the same.

F. E. LINDSAY
Birmingham, April 16, 1957.

THE HYDRO-PNEUMATIC ENGINE

SIR,—I read with interest about the "interesting and valuable apparatus" described in your issue of February 20, 1857, and reprinted in your issue of February 22, 1957. It may interest your readers to know that certainly up until recently and perhaps even yet an "apparatus" of the type described was in use at St. Andrews-by-the-Green Episcopal Church in Glasgow. I believe that the organ and blowing engine in question were removed from Glasgow Cathedral in about 1810, but this may apply merely to the organ itself. I have been unable to verify the facts about this equipment, but it would be of interest to discover whether any of your readers know of anything similar still in use elsewhere. The chief criticism of the apparatus seemed to be the noise it made. This, of course, may just have been due to age.

E. F. CLARK, M.A., A.M.I.Mech.E., A.M.I.Loco.E.
Glasgow, April 17, 1957.

Book Reviews

The Drawing Office Handbook. Edited by R. W. STUART MITCHELL. Sir Isaac Pitman and Sons, Ltd., Pitman House, Parker Street, Kingsway, London, W.C.2. Price 16s.

THIS very useful work has now entered into its third edition, and the opportunity has been taken to extend its scope considerably. As before, there is a skilfully compiled digest of British Standard Specifications that are of special concern to the drawing office, and these are now supplemented by a series of signed contributions on the more generally encountered aspects of a designer's work. In present-day practice, a single drawing office could be dealing with light press work, castings, forgings, and plastics—quite apart from the general run of machining. Every designer cannot be an expert in all processes, and the handbook provides a very useful guide ; not a short cut to an adequate answer, but a guide to the existing authoritative works on a subject, and where to find them. It postulates the considerations that have to be taken into account, and discusses

the factors that make it necessary to apply corrections in certain cases to basic theoretical formulæ. The special contributions deal with design formulæ, properties of materials, welding, mechanical power transmission, gear design, springs, lubrication, mechanical vibration, noise, electrical technology and electronics.

The Drawing Office Material Manufacturers' and Dealers' Association, under whose auspices the book is published, is to be congratulated on the contributions secured, and the practical approach shown in the treatment of each subject. We were, however, rather surprised to find that extracts from the British Standards Specifications dealing with rolled steel sections included in the digest are confined to channels and joists. It would have been well worth while to include the angles as well. These latter are in constant use in many branches of engineering apart from purely structural work, and this reference to steel sections leads to another important consideration in all design work to-day, to which we could find no reference in the handbook. There are references to the need to select the correct materials for the duty, but at the present time there is great difficulty in obtaining supplies of the higher grade alloy steels. A 3 per cent nickel-chrome molybdenum steel might be ideal for a particular application, but the designer has to consider its availability, its price, and the length of time for which delivery must be awaited. Shortages of materials, particularly where rolled sections are needed in small quantities, loom so large in the daily round of so many designers to-day that a contribution on the practical politics of design, indicating the pitfalls to be encountered, might well be considered for a future edition of this excellent book.

Engineering Structural Failures. By ROLT HAMMOND, A.M.I.C.E., Odhams Press, Ltd., 96, Long Acre, London, W.C.2. Price 25s.

IN his foreword to this book, Sir Bruce White draws attention to the importance of understanding the "casualties and accidents" of civil engineering. "We fully understand the desire of an engineer to conceal careless mistakes," he writes, "with these we are not really concerned. It is in the genuine errors of judgment in design and execution, in the failure fully to understand site conditions and to foresee consequences, that we are so vitally interested."

It is, of course, well known that some failures of this kind have had a revolutionary effect on engineering practice, and a study of failures is generally rewarding. Some of the well-known and instructive ones are described in this book. We must express a doubt, however, whether in some cases the descriptions given are sufficiently detailed, or the analyses sufficiently searching, to demonstrate the engineering lesson which the case presents, in as complete a manner as would seem desirable.

Nevertheless, the idea of gathering together all these engineering failures, grouped according to the class of work involved, was a good one, and there is much in the book to interest most civil engineers. There is also a bibliography attached to each chapter, so a more detailed investigation of any particular example can be made.

Messung mechanischer Schwingungen. Richtlinien VDI, 205–210, VDI-Verlag GmbH., Düsseldorf. Price DM.52.50.

THIS German book on the measurement of mechanical vibration is published by the Society of German Engineers (VDI) as a code of practice. It has been compiled with great attention to detail and its contents fall under ten main headings. These are: (1) definitions and formulæ; (2) technical problems of vibration measurements; (3) measuring instruments; (4) sources of excitation; (5) balancing machines; (6) principles and practice of vibration measurement; (7) recording and analysis; (8) determination of the main parameters of a system from measurements taken; (9) further notes on the theory of mechanical vibration; (10) bibliography.

The bibliography is possibly the weakest part of the book. Although it contains over 600 references, most of them being to continental literature, many of the more important recent papers published in this country and in the U.S.A. are not mentioned. For instance, no reference is made to the powerful receptance techniques that have been developed in this country during the last twenty years. Apart from this, however, the book is an excellent one. It contains a mass of information which is clearly set out with great precision. It cannot fail to be of value to vibration analysts.

This book inevitably raises the question of whether or not a similar code should be drawn up in this country. There is no comparable volume in the English language as far as we are aware.

The Whitworth Register. Editors: H. H. JOHNSON, Wh. Ex., M.I.Mech.E., F. T. BARWELL, Wh.Sc., Ph.D., M.I.Mech.E., The Whitworth Society, 1, Birdcage Walk, London, S.W.1. Price 42s.

IN 1926, the Whitworth Society produced the "Whitworth Book" which listed the 1400 men who had by then benefited directly from Sir Joseph Whitworth's foundation. In 1940 stocks of this book were destroyed by enemy action, and it has now been replaced by the Register. This includes a memoir of Sir Joseph, and an account of the Scholarships, Senior Scholarships, Exhibitions and Prizes. The Regulations for the Fellowships which are currently awarded are given, and it appears that the Society will no longer be limited to men. There is a table showing the origins of scholars and exhibitioners which discloses some interesting facts: for instance, only 5 per cent of the Englishmen came from Yorkshire. The bulk of the book is an alphabetical list of Whitworth men, including one whose house is named "Whitworth."

Born of Fire—Steel: A Color Picture Book. Verlag Die Schönen Bücher. DR. WOLF STRACHE, Stuttgart N., Ossietzkystrasse 6. Price DM.35.

OVER one hundred colour photographs by C. A. Stachelscheid, with captions by Heinz Todtmann, illustrate the manufacture and uses of steel, beginning with the raw materials—coal, ore and limestone—and proceeding by way of coke oven, blast-furnace, Bessemer plant, open hearth process, and electric arc furnace, to the rolling mill, and from there to the manifold uses of rolled steel plates, sheet and tubes. The illustrations, skilfully taken and well produced, convey successfully the sense of excitement and adventure underlying modern technology.

Books Received

The Final Forming and Shaping of Wrought Non-ferrous Metals. The Institute of Metals, 17, Belgrave Square, London, S.W.1. Price 21s.

Statistical Year Book of the World Power Conference No. 8. By Frederick Brown. Percy Lund, Humphries and Co., Ltd., 12, Bedford Square, London, W.C.1. Price 63s.

British Standards Institution

All British Standard Specifications can be obtained from the Sales Department of the Institution at 2, Park Street, London, W.1.

TESTS FOR USE IN THE APPROVAL OF WELDERS

No. 2645 : 1956. Part 2, "Manual Metal Arc and Oxy-Acetylene Welding of Mild Steel and Low-Alloy Steel Pipelines and Pipe Assemblies." Price 10s. Part 2 of this specification deals with mild steel and low-alloy steel pipelines and pipe assemblies and is a companion standard to Part 1, which dealt with mild steel and low-alloy steel sheets, plates and sections.

The purpose of these standards is to make available a series of agreed standard tests, one or more of which can be selected for assessing and testing the capabilities of a welder. The tests given in it cover various thicknesses of tube, normal forms of joints and various welding positions, and the standard is complementary to B.S. 1295, "Tests for Use in the Training of Welders," which gives tests designed to assess the progress of trainees.

The tests for use in the approval of welders for specific applications to pipe fabrications comprise butt welds and fillet weld branch joints for both structural and flow pipe work and apply both to the arc and to the oxy-acetylene processes. They do not however, meet the requirements covered by B.S. 1821 or B.S. 2633.

It is pointed out that a welder who passes certain of the more difficult tests may be assumed to be capable of passing some of the simpler tests. Hence, in deciding on the tests to be applied to a particular welder it will often be found possible to select one of those corresponding to the more difficult joints on which he will be employed, thus minimising time and expense of testing. The welding procedure, pre-heating and post-heating, and the specifications for the electrodes and filler rods to be employed, particularly for the welding of low-alloy steels, should be in accordance with the application standards where these exist, and in the absence of such standards they should be stipulated.

Appendices in the specification give notes on the alternative sizes of electrodes, suggested methods of preparing etched specimens and the method of preparing and testing bend test specimens.

TERMINOLOGY OF INTERNAL DEFECTS IN CASTINGS AS REVEALED BY RADIOGRAPHY

No. 2737 : 1956. Price 12s. 6d.—The need for rationalising the terminology of defects in castings was realised when the Non-Destructive Testing Group (formerly the Industrial Radiology Group) of the Institute of Physics initiated the preparation of the present standard. Different workers in the field, such as radiologists, metallurgists, foundrymen and engineers, commonly use various terms for one type of defect and also at times use the same term for more than one defect. There is variation from industry to industry, and even from foundry to foundry, and the purpose of this standard is to enable the interpretation of casting radiographs to be understood without ambiguity of terminology, by those interested in the radiographic inspection. To this end the terms have as far as possible been chosen to correlate the definitions with their metallurgical or foundry origin. The aim has been to select those terms which will be applicable to all the metals normally used in castings.

The defects listed have been classified into five groups of associated types with sub-divisions. A separate section is included relating to diffraction mottling, which arises from purely crystallographic causes, and should not be regarded as a defect.

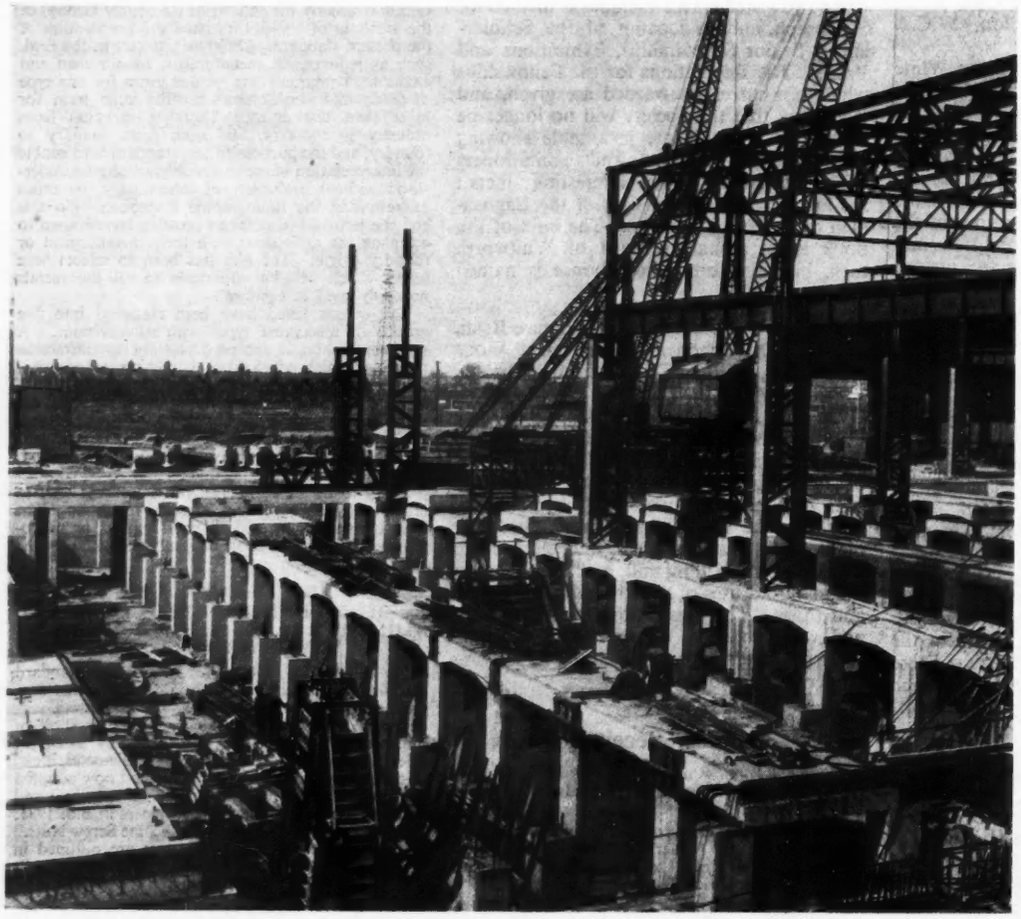
The terms and definitions used in the standard are illustrated by radiographs, which have been selected, not only to show the salient features of the defects, but also because of their suitability for reproduction. These illustrations are intended solely to be complementary to the definitions of the defects and not as criteria of their severity. Some of the radiographs have been supplemented by macrographs or micrographs to help in the appreciation of the nature of the defect.

100 DEG. COUNTERSUNK PRECISION HEAD ALUMINIUM AND ALUMINIUM ALLOY RIVETS FOR AIRCRAFT

No. SP. 68–71 : 1956. Price 3s. 6d. This standard specifies the materials, dimensions, finish, marking, part numbers and inspection of the rivets. A departure is made from the traditional method of dimensioning countersunk head rivets by means of toleranced dimensions for the head diameter, head thickness, land and angle. The method now adopted is known as the "flushness tolerance" method and was first used for countersunk fasteners in B.S. 1981, "Unified Machine Screws and Machine Screw Nuts." Its basic principles and advantages are outlined in the appendix to the standard, which also gives details of suggested methods of gauging.

Civil Engineering in Heavy Industry

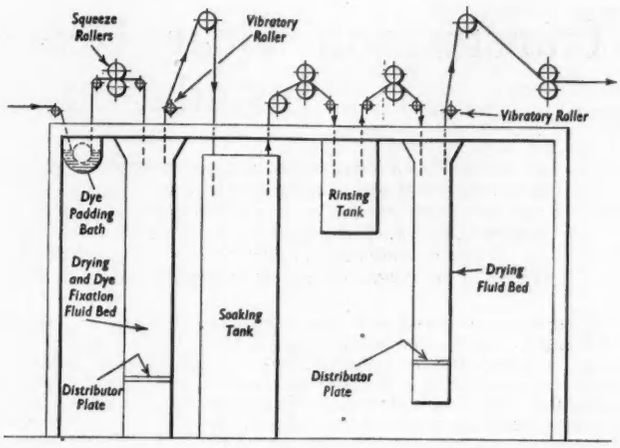
Progress by April 14 last of excavation and other works for the two reactors at Berkeley nuclear power station in Gloucestershire. No. 1 reactor pit in the foreground is in the process of being concreted. The indentations around the pit are the sites for the heat exchangers. To the left is the excavation for the turbine hall. In the right foreground is the pressure vessel erection slab. The camp in the background is temporary accommodation for some of the labour employed on the site. The Berkeley power station is being built for the Central Electricity Authority by A.E.I.–John Thompson Nuclear Energy Company, Ltd. The civil engineering contractors are, for the two reactor pits John Laing and Son, Ltd., and for the turbine hall and camp Balfour Beatty and Co., Ltd. The civil engineering consultants are W. S. Atkins and Partners



A new press shop under construction at the Dagenham works of Briggs Motor Bodies, Ltd., as part of the Ford modernisation and expansion scheme. The site has been excavated to give a basement floor 17ft below ground level; it will be possible to deploy presses wherever they may be required on the pedestals seen in the foreground. The presses will feature underfloor scrap disposal, and the scrap will be removed by conveyors in the basement. The total cost of this shop and an extension of the existing press shop will exceed £5,000,000; the contractor is Marples Ridgeway and Partners, Ltd., and the consultants are Messrs. Posford Pavry and Partners. Completion is expected towards the end of this year

Fluid Bed Technique for the Textile Industry

A new textile processing technique, which was mentioned in THE ENGINEER *of March 22, has been developed by the British Rayon Research Association and incorporates a "fluid bed." This is an efficient means of conveying heat and the system evolved permits a continuous process to be employed and results in a reduction in the time required. A small pilot plant built by the British Rayon Research Association for experimental work is outlined here.*



THE principle of the "fluid bed" and its efficiency as a means of removing or supplying heat have been known for a number of years. An example of the employment of a fluid bed, particularly since the war, has been in association with the refining of oil in this country where the system has been adopted as part of the catalytic cracking units forming part of the refinery installation. It was the high heat transfer characteristics of the fluid bed that claimed the attention of the British Rayon Research Association, and in 1954 the Association began exploring the possibilities of applying the system to the textile industry. The investigations were directed towards exploiting the potential value of the fluid bed to those textile processes involving heat transfer such as fabric drying, resin baking, printing and certain methods of dyeing. During the processing of cloth it may be required to pass several times through the cycle of wetting and drying. Fabric drying is usually carried out by passing it over heated rollers or by employment of hot air, both of which methods have low thermal efficiencies. Thus, a considerable amount of heat is required and an expenditure on fuel which the adoption of the "fluid bed" would reduce considerably. Furthermore, hot air driers and other equipment represent a high first cost and occupy a considerable amount of valuable floor space, much greater than that required for a "fluid bed" drier.

Essentially, the "fluid bed" consists of particles (such as glass beads of 100 microns to 1mm diameter) through which air is passed after being distributed through a bottom plate, the velocity of the air upwards through the bed being that which will provide a viscous drag sufficient to counterbalance gravitational force. From a static position there are roughly three stages before the bed becomes fluid, depending upon the velocity of the air. In the first stage the particles are in suspension but still packed down, while in the second, with increased velocity of air, there is an increase in free space, but the particles are unable to move freely and are still in contact. The third stage is reached when, with a further increase in the air rate, a boiling bed is produced in which the particles move vigorously and are supported in the air stream. In this latter state the bed resembles a liquid so that the mass of particles takes the shape of any containing vessel and the pressure is hydrostatic, being a linear function of the depth. In common with a liquid the fluid bed has high heat transfer properties, the rate being approximately 60 B.Th.U. per square foot per hour per degree Fah. Several methods are suitable for heating the beds, such as steam coils, pipes taking hot water under pressure, tubes in which are burnt oil, or gas, and electric coils. The above could be used not only in the textile industry, but in other industries and depending upon the process, live steam above the condensation temperature could be passed directly through the bed and used as a fluidising medium. Again, gas mixed with air and burnt within the bed could be used for high-temperature beds.

The system of heating enables temperatures to be maintained with a high degree of accuracy, and another factor of considerable importance is that the degree of heat is uniform throughout so that the fabric in passing through is dried evenly on both sides simultaneously. The temperature will vary according to the process, 200 deg. Cent. being required for the setting of "Terylene" and "Nylon" to fix permanent pleats, and somewhat lower temperatures to produce crease-resistant material. To produce the latter, the cloth is impregnated with a solution of urea formaldehyde resin at a low degree of polymerisation, after which the surplus liquor is squeezed out and the cloth is dried off followed by baking to polymerise the resin. Incidentally, the moisture may be dried off and the resin baked on in a single operation lasting about twenty seconds, whereas this kind of finish normally requires two separate operations. Somewhat similar procedure is used in the fluid bed technique to produce printed cloth, the pattern consisting of a mixture of pigment and binding materials which are baked on after removal of the surplus moisture.

Attention has been drawn already to the frequent drying stages, which may be as many as three or four, in the processing of fabric, and at each stage as much as 80 per cent of its own weight may have to be removed from the cloth. This underlines the importance of the heat transfer properties of the fluid bed and tests, using medium weight cotton or viscose cloth, have established that a fluid bed, having as a heating medium tubes heated by steam at 100 lb per square inch gauge, used 1·4 lb of steam for each pound of water evaporated: a high percentage of efficiency, which is overall since no fan horsepower was required. When similar cloth is dried in the most modern of stentor driers, the overall efficiency is approximately the same, about 1·5 lb of steam being required to evaporate 1 lb of water, but, in addition, a large allowance for the power used must be made to provide the necessary high velocity air used in such systems.

In an experimental full-scale plant, which is capable of handling cloth 40in wide and has a bed 6ft deep filled with small glass beads known as ballotini, 18 lb of water per square foot of fabric per hour have been evaporated, which may be compared with the rate of 7 lb per square foot per hour claimed for the best of the conventional dryers. The ballotini used may range in size from 100 microns up to 1mm in diameter. The rate of evaporation achieved translated into terms of time means that 4 oz fabric can be dried in approximately five seconds, the linear speed of the material being about 12ft in five seconds when a double pass system is employed, or half that speed when a single pass system is used. In a double pass system the material enters at the surface of the bed and passes downwards to a bottom roller and then upwards to the surface, having traversed the depth of the bed twice. For single pass drying the material enters the bed at the bottom and passes upwards to the surface. Both methods have their engineering difficulties, and in the first the roller has to be perforated to allow the air, which is introduced, to pass upwards through the bed above the roller in order to keep the particles boiling in that section. In single pass drying provision has to be made to enable the fabrie to enter the base of the bed without particle loss.

The general scheme involving the use of a fluid bed drier is embodied in our line drawing of a small pilot plant, which was constructed by the Association for experimental purposes. These referred particularly to the dyeing of "Terylene," "Nylon" and acetates with acetate dyes. A light steel framework approximately 8ft long by 5ft high by 18in wide houses the essential plant, which consists of a dye padding bath, a soaping tank, a rinsing tank and two fluid beds, one for drying and dye fixation and the other for drying. The fluid beds are about 2ft deep and are electrically heated, and the air, which is delivered by a fan, passes through the porous ceramic distributor plate, across which the pressure drop is relatively low, and upwards through the bed. Some hundreds of yards of cloth have been successfully dyed in the experimental plant through which spun "Terylene" cloth 6in wide is passed at a speed of 12ft per minute.

The cloth is first passed through the dye padding bath, containing a dispersion of dyestuff in water, and the surplus liquor is removed by squeeze rollers before entering the first of the fluid beds where the material is dried and the dye fixed. Then followed treatment in the soaping tank before passing through squeeze rollers into the rinsing tank and then through another set of squeeze rollers previous to entering the second fluid bed drier. The temperatures of the fluid beds are respectively 190 deg. and 150 deg. Cent., and it will be noticed that in this instance the double pass system is in use. Rotating rectangular bars are used to vibrate the cloth as it leaves the fluid bed in order to detach any particles which may be adhering to it.

One of the normal commercial methods of dyeing fibres such as "Nylon" and "Terylene" is to impregnate them with dye under pressure in an autoclave, and is essentially a batch process requiring a considerable amount of time. In comparison the fluid bed method makes it possible to dye these materials by a dry heat fixation process in a few seconds and, of course, the process is continuous. Another important application where the fluid technique is much quicker than present methods is the processing of latex coated tyre cords and there are opportunities to make use of the technique in the production of tufted carpets and many other products which require to be rapidly dried.

To exploit this development a group of firms has been formed to co-operate with the Research Association in solving the general engineering problems and to manufacture and market fluid beds. The group includes British Tufting Machinery, Ltd.; Hunt and Mosscrop, Ltd.; Mather and Platt, Ltd.; F. Smith and Co. (Whitworth), Ltd., and Tomlinsons (Rochdale), Ltd.

Transmission Gear Heat-Treatment Installation

To provide for an increasing demand for automobile transmission gears and their heat-treatment to very exacting specifications a new heat-treatment installation has been developed by David Brown Industries, Ltd., for the firm's Automobile Gearbox Division. This installation is arranged in three lines covering gas carburising, salt bath treatment, and induction hardening. It is designed to permit close control at all stages and ease in handling a variety of parts in small batch lots.

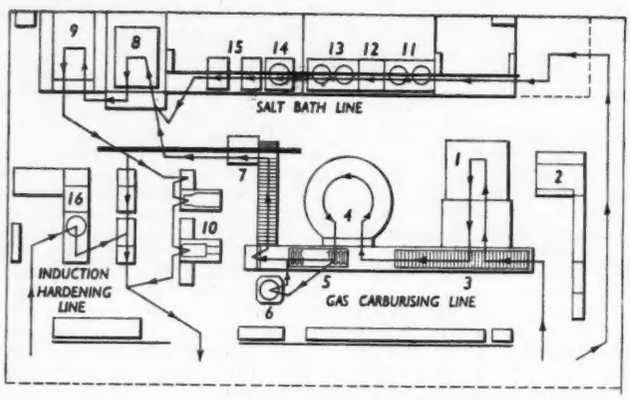
A NEW heat-treatment section, which has been installed by the Automobile Gearbox Division of David Brown Industries, Ltd., Park Works, Huddersfield, is designed to process a weight of 1000 lb of commercial vehicle transmission gears every seven hours. Before this new section was introduced the firm carried out all production carburising by the pack method, using horizontal electrically heated batch furnaces. These furnaces took a 3000-lb charge of work, which was loaded by mechanical means. Reheating was done in smaller electric furnaces and the parts were free quenched in conventional tanks. The gear manufacturing procedure followed at that time was of such a nature that there were no acute problems in heat-treating the work. When, however, gears were introduced with shaved instead of profile ground teeth, and straight-sided splines were replaced by those of involute form, certain problems were encountered. There was a demand for greatly reduced distortion in heat-treatment, together with better preservation of surface finish and freedom from superficial damage with increased fatigue resistance. These more exacting requirements made it necessary to introduce new methods of heat-treatment.

Extensive investigations were carried out in connection with heat-treating gears and eventually the three-line section shown in the accompanying diagram was evolved and installed in the works.

The first and main heat-treatment line was planned to take the bulk of the transmission gears which flowed in regularly and in suitable batch quantities and weights. For carburising these parts a horizontal gas carburising plant heated by radiant tubes was chosen. The firm states that this changeover from electric element to gas heating was decided upon as the use of radiant tubes not only meant that the nickel-chrome lining (always a potential source of maintenance worry) could be dispensed with, but it also eliminated need for an external atmosphere generator, since the tubes themselves could be designed for this purpose. Furnaces of this type are generally constructed to allow for direct quenching of work, but since most gearbox gears need individual attention during quenching, the construction was altered so that the work could be cooled slowly in a gastight pit.

Under the procedure followed the gears are packed in rectangular containers standing on a roller conveyor of convenient height, and when packing is completed the charge is raised to the furnace sill on a hydraulic table so that it can be pushed into the vestibule of the furnace. From this point onwards the charging operation is automatic, as all the furnace movements are push button controlled. In the sequence the outer vestibule door is closed before the inner door is opened and then two rotating screws draw the box to the rear of the furnace. The heating rate of this furnace is greater than usual, as powerful forced circulation is provided through the charge, while special refractory walls between the tubes and the boxes serve to store heat. Throughout the heating cycle a neutral carrier gas is generated in the inner tubes, an arrangement which prevents scaling or decarburisation of the work. During the active carburising stage the atmosphere is enriched with butane gas metered into the furnace.

In order to obtain the optimum quality with the simplified heat-treatment, fine-grained steels are used exclusively for the gears and the processing temperature and the active carburising diffusing time ratios are closely controlled to give the most suitable carbon gradient in the case and obviate grain coarsening of the core. It is pointed out that although "normal" rather than high temperatures are used in the heat-treatment the rapid heating ensures a short carburising cycle and with this equipment a charge of 1000 lb of work can be processed every seven hours. There is no undue delay in emptying and recharging the furnace since the completed charge can be transferred from the furnace and sealed in the cooling chamber without need for opening the outer door.



1. Gas carburiser.
2. Control panels.
3. Work conveyor.
4. Rotary hearth furnace.
5. Quench tanks.
6. Die quench press.
7. Degreasing unit.
8. Shot blast cabinet.
9. Tempering furnace.
10. Straightening presses.
11. Salt carburising unit.
12. Cooling pot.
13. Salt hardening unit.
14. Quench tank.
15. Wash tanks.
16. Induction heating unit.

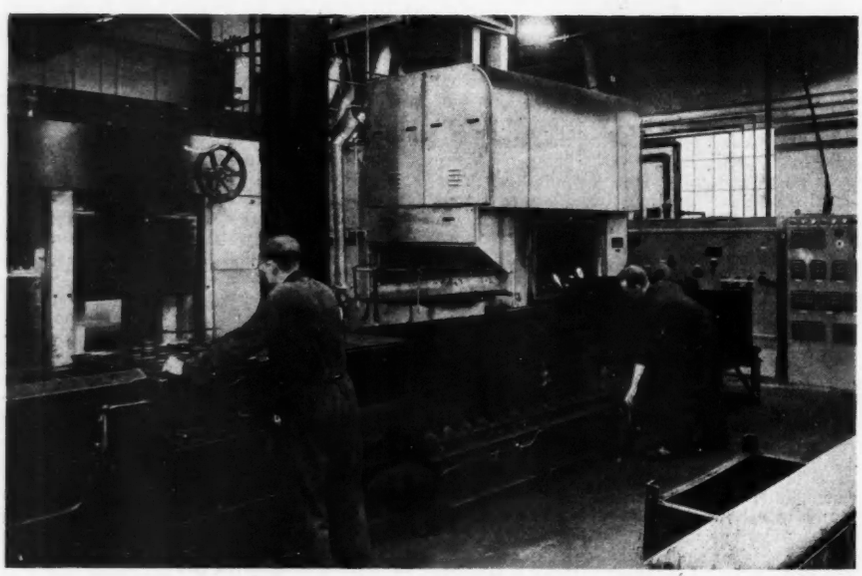
Work flow through three-line heat-treatment section

When the charge has cooled to room temperature it is transferred along the conveyor to a variable-speed rotary hearth reheating furnace. This furnace, which is electrically heated and atmosphere sealed, can be seen in the accompanying illustration. A sill is provided at charging level for the furnace and the quenching tanks are set immediately in front of and under the discharge door, an arrangement which eliminates need for lifting and carrying hot work. To avoid possibility of the oil vapour igniting when the discharging door is opened the tanks have been made as small as possible, and an extracting system fitted just above oil level prevents the escape of fumes out of the top of the tanks. The furnace doors are operated by pedals so that the operator's hands are free to manipulate the valves controlling the hydraulic tables inside the tanks. No up and down movement of the work is required, as the quenching oil is pumped into the tanks at a rate of 300 gallons per minute to provide sufficient agitation with the table stationary in the tank.

After hardening the gears are taken along another horizontal conveyor to degreasing and shot blasting stations. To give ease of handling both the shot blasting cabinet and the subsequent tempering unit have been set in pits to reduce need for lifting as far as possible. The tempering unit hearth is level with the floor and containers with as much as half a ton of work can easily be charged into the furnace by a small lift truck.

A second heat-treatment line is used for small quantity parts and those which cannot be accommodated economically in the gas carburising unit. It consists of salt bath furnaces, cooling pits, quench and washing tanks, all of which are arranged in a rectangle and enclosed by a hood with an independent fume extraction system. A monorail hoist with a station index serves to transfer the work, which is carried in baskets, between the units in the line.

The oil system for the quench tanks here



Rotary hearth furnace with built-on quenching tank. Work is charged through the right-hand door and is discharged through the door shown on the left

presented difficulties, since it was considered desirable not to incorporate conventional heat exchangers. The solution was provided by the installation in the basement of two oil storage tanks of larger capacity than normal. Oil is pumped up into the quench tanks and then returned over weirs and down special ducts, where it is cooled by natural air convection.

An induction hardening line has been installed for the heat-treatment of the large amount of non-gear parts fitted in a modern gearbox which require some form of local hardening. It was found that the conventional design of induction hardening workhead would not be capable of processing the wide variety of parts concerned, and after consultation with the makers it was decided to install a 25kW valve oscillator set with the energy output leads coupled to a capstan workhead, an arrangement which allows four permanent hardening fixtures to be used. Since the main application is the surface hardening of selector rods, a vertical traverse is incorporated in the head and all switching of the high-frequency power is controlled by switch contact templates made to suit each design of rod.

This installation is also used to anneal the hardened keyways and screwed portions of shafted gears, and need for copper plating work treated in the gas carburising line has been eliminated.

We are informed that at present work is in progress on the design of an automatic programme controller for the gas carburising unit, which, when installed, will control the furnace atmosphere and the carburising cycles, thus making the carburising operation fully automatic.

Spares Storage and Handling

THE first project to be completed under the £65,000,000 expansion programme of the Ford Motor Company, the depot and headquarters of the Parts Division at Aveley, Essex, is now in operation. On a recent visit to the establishment we were able to see the methods used for storing and issuing the 31,500 different items serviced; the magnitude of the organisation is indicated by the fact that it handles the spares required by 2,250,000 English Ford vehicles, as well as industrial units.

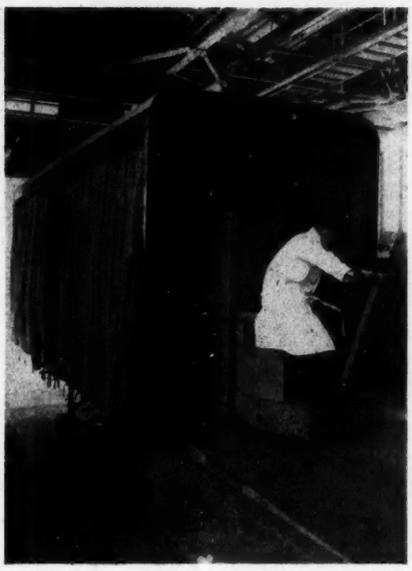


Fig. 2—Dock levellers, raised by rams, allow vehicles to be unloaded by handling equipment. The semi-trailers have reinforced floors to stand the high point pressure of pallet trucks

The building is a single-storey light-framed steel structure with a north light roof, brick and glazed walls, and a reinforced concrete floor; at one end there is a two-storey office block accommodating the parts headquarters. It was commenced in August, 1955, and within ten months stock was arriving from the many locations that had previously been maintained in various parts of England. The organisation is now concentrated on the new site.

The building was designed around a materials handling concept; the parts involved are reasonably light, ranging up to the chassis of a Thames truck. They arrive principally by road at one of five double bays on one side of the depot. Components manufactured by Ford or Briggs Motor Bodies at Dagenham travel the intervening 8 miles in special semi-trailers, 23ft long and carrying 8 to 9 tons, which are drawn by Thames tractors with "4-D" engines. One is seen in Fig. 2; the internal height is 7ft 3in. To allow pallet trucks to be driven into and out of the vehicle, regardless of the load on the springs, power-operated levelling ramps are installed; once these have been laid on the vehicle platform by an operator, they remain in line with it as it is unloaded.

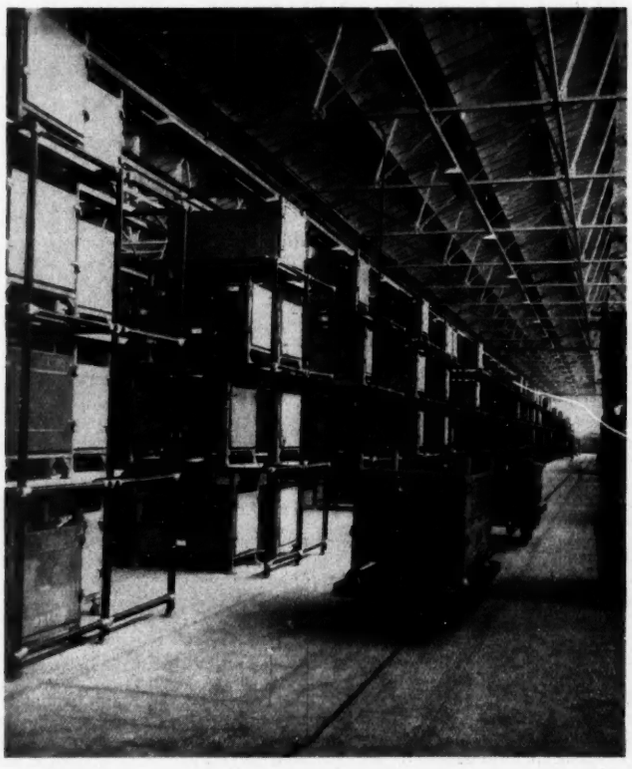


Fig. 1—The pallet racking allows 7ft aisles for access by reach trucks. Trolleys are drawn by an under-floor chain right through the stores

Along the greater part of the length of this side of the building runs the "Towveyor." This is an endless underfloor conveyor, which tows rubber-tyred trolleys on a 3200ft circuit of the works. The conveyor, supplied by Jarvis B. Webb, Ltd., Bexley, Kent, is driven by two 10 h.p. electric motors; powder clutches are incorporated to allow the motors to accelerate unloaded, and as a safeguard against the chain being stalled. Trollies of two sizes, the 2-ton version seen in Fig. 1 and a ½-ton model, are used. To start a trolley a bolt at its nose is dropped through the conveyor track; when a dog, one of which occurs every 20ft on the chain, arrives, the bolt rides up a ramp at the leading edge and settles in a recess. The trolley then moves with the dog—it will have been left at an angle to the track to allow it to gather momentum gradually. When it reaches the point at which it is required the bolt is lifted and it comes to rest. The travelling speed is 80ft per minute. If necessary, the conveyor can be stopped by controls at many points along its travel: when it is reset a horn blows and six seconds elapse before the chain moves.

The "Towveyor," having passed along the input side of the depot, works back through the stores on a route which outlines a letter **E**. It passes first through the bin section, where small parts, usually wrapped, are kept, then through the heavy section, holding springs, half-shafts, and other far-from-fragile items, and then up and down the packing section, domestic and export. It then passes along the despatch bays, opposite to the receiving bays, and reaches the receiving side around the large area devoted to storing sheet metal parts.

On the outside of the conveyor circuit are sections devoted to inactive stock, mainly parts for obsolescent vehicles, an immersion tank for corrosion-inhibiting parts susceptible to deterioration, and a casemaking shop, which takes sawn timber and, employing principally power-driven woodworking machinery, produces packing cases.

In the heavy section the post pallets are stowed in tubular steel racking. Space has been saved by the use of reach trucks for stacking, since these vehicles require only 7ft aisles instead of the 12ft needed by fork-lift trucks. The closely packed racks, in four tiers, can be seen in Fig. 1.

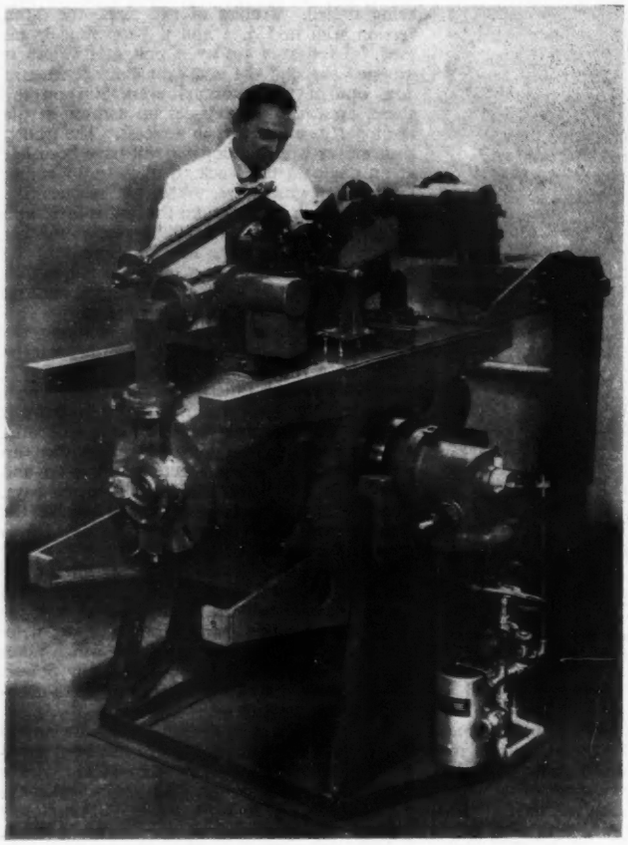
The main stores building is maintained at 65 deg. Fah. by forty-one "Dravo" oil-fired space heaters, thermostatically controlled and burning gas oil. The offices are steam heated by boilers burning heavy fuel oil. Lighting is by fluorescent tubes. The parts depot employs 800, and the headquarters 400 personnel.

Each part has its own location in the stores, which information is automatically shown on the invoice by a punched card system. Thus the operative making up the order—"picking"—does not have to search for it. The organisation is such that routine monthly stock orders are fulfilled in about seven days or, for overseas shipments, two to three weeks. In the case of a vehicle being immobilised for lack of a part a twenty-four-hour service is provided.

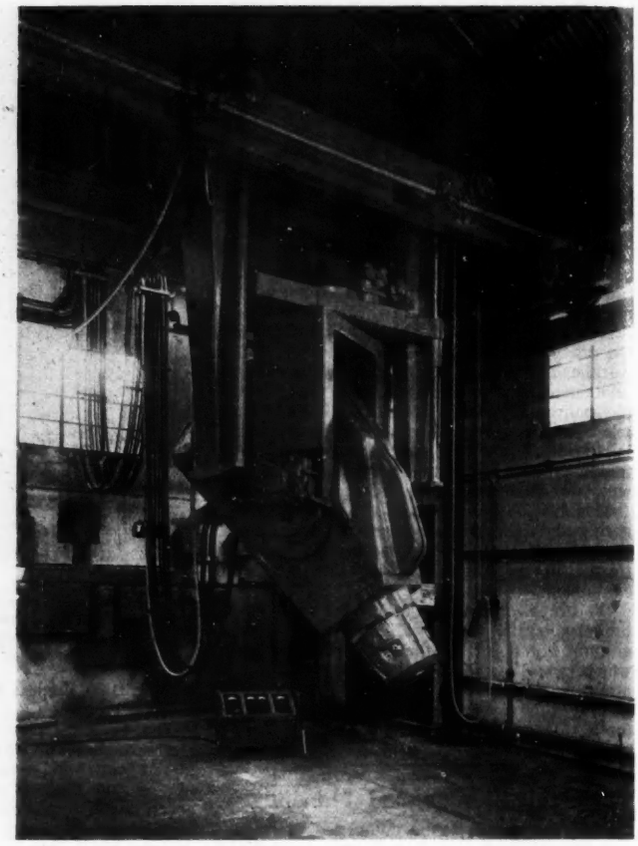
Joint for Polythene Tubes

A COMPRESSION joint of plastic material for polythene tubes has been developed by Mange Plastics, Ltd., 39–41, Margravine Road, London, W.6. This form of joint can be readily assembled by unskilled labour, broken and remade repeatedly: it is stated to have a most satisfactory performance under high-pressure loading, static pressure, pressure at high temperatures, freezing, and other conditions. The joint is prepared by belling the ends of the polythene tubes, by heating in hot water and the insertion of an ordinary plumber's cone bell. There is then introduced into these ends a rigid olive member moulded from high density polythene. An internally threaded nylon ring is slipped over one of the tubes and a back nut over the other, the bore in each of these members being tapered to correspond with the bell form of the tube ends. As the back nut is tightened in the nylon ring the tubes are drawn together and compressed on the olive member in the tubes to form a rigid joint.

A range of these "Polytite" fittings, as they are known, includes straight couplings, elbows and tees in sizes to fit ½in, ¾in and 1in bore tubes; reducers to adapt one bore size to another; adjusters for coupling different gauge pipes; and adaptors to connect polythene to metal pipes.



5MeV linear accelerator for industrial radiography. The accelerator is shown here, without covers, during assembly. The wave-guide system is at the top and the diffusion pump with rotating vacuum joint is at the right



Linear accelerator mounted on overhead rails with longitudinal and cross traverse. The X-ray head can be rotated and the accelerator can be tilted from horizontal to vertical. All controls are push-button-operated through trailing cable

5MeV Linear Accelerator for Industrial Radiography

A 5MeV linear accelerator made by Mullard, Ltd., Torrington Place, London, W.C.1, has been installed at a Ministry of Supply establishment. This accelerator is believed to be the first of its kind to be designed specifically for industrial radiography. It is stated that a half-hour exposure using the linear accelerator will give a radiograph of optimum definition of a steel specimen 9in or 10in thick.

The 5MeV linear accelerator has been designed to give very fine definition : despite the high energy and the large output (over 500 roentgens per minute at 1m), the electron beam which creates the X-rays has a diameter of only 2mm when it strikes the target. In addition, because of a special new magnetic focusing device associated with the X-ray head, the polar diagram of the output tends to be flatter than is normally associated with such a high energy beam.

As can be seen from the second illustration, the complete equipment is mounted on overhead rails so that its transverse and longitudinal movements enable it to be brought within working range of anything to be radiographed on the shop floor. In addition the whole equipment can be raised or lowered 8ft ; the accelerator itself can be turned laterally through 180 deg. ; it can be tilted in any direction from the horizontal to vertically downwards ; and, finally, the X-ray head can be rotated. These movements are controlled from the floor by grouped push-buttons at the end of a trailing cable, as illustrated ; the control cabinet can be seen below the accelerator.

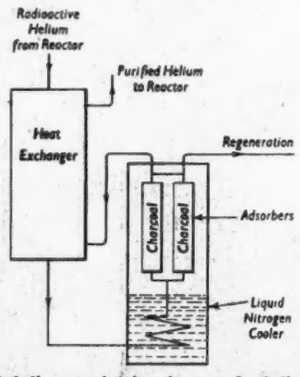
In the interests of mobility the main part of the machine has been kept small ; the overall length is 9ft. Our second illustration shows the accelerator during assembly and with the covers removed. The wave-guide feed-back system can be seen at the top of the casting, with the " rat-race " immediately in front of the man. The magnetron is mounted vertically at the right-hand end of the assembly. In the centre of the framework is the accelerator drum, at the left-hand end of which is the output, whence the electrons pass through the focusing lens. This lens had not been fitted at the time when the photograph was taken. The diffusion pump can be seen at the right-hand side of the framework and just to the left of the elbow is the 6in diameter rotating vacuum joint which allows the pump to remain vertical when the accelerator is tilted.

The 5MeV linear accelerator was designed and built by Mullard Research Laboratories on behalf of Philips Electrical, Ltd., the contractor for the supply of the whole equipment.

Helium Drier and Adsorber for "Dido" Research Reactor

A HELIUM drier and adsorber has been supplied by British Oxygen Engineering, Ltd., for the " Dido " research reactor of the U.K. Atomic Research Establishment at Harwell. This reactor uses highly enriched uranium fuel cooled and moderated by heavy water, and if the hydrogen and oxygen resulting from the splitting up of the heavy water by radiation were allowed to accumulate, an explosive atmosphere could be produced in the reactor. To remove these unwanted gases and any possible air ingress, helium is employed in a closed circuit, which means that the helium itself has to be purified. The difficulty is to remove completely small amounts of impurity in a plant of reasonably small dimensions. On the principle that the lower the temperature the greater the adsorbent capacity (resulting in a smaller volume of helium at a higher velocity in a smaller container), the method adopted has been to cool the helium down to the boiling point of liquid nitrogen (−196 deg. Cent.) and then to pass it over a special kind of active charcoal. Considerable *ad hoc* experimentation was devoted to finding the right kind of charcoal pieces, and their optimum size under operating conditions.

An outline of the purification process is given in the diagram. The radioactive helium emerges from the reactor at about ambient temperature and is precooled in an aluminium-sheathed heat exchanger through which the purified gas is passed on its way back into the reactor. From the heat exchanger the helium then passes to the liquid nitrogen cooler which, together with the adsorber, is encased in a stainless steel cylinder. The adsorber is arranged in tandem for batch operation, only one section being used at a time. Periodically, the charcoal in each section in turn



Simplified diagram showing the use of a helium drier and adsorber for removing unwanted gases in the heavy-water research reactor " Dido " at Harwell

has to be regenerated, which is done by a combination of an increase in temperature and evacuation of the hydrogen, nitrogen and oxygen by means of a vacuum pump. In the cooler the level of the liquid nitrogen (brought to Harwell in British Oxygen insulated containers and replenished regularly) is kept constant.

Because the fluids involved are radioactive, the whole plant, which measures approximately 5ft 6in by 4ft by 10ft, must be free from the risk of leaks. Special attention was, therefore, given to welding techniques and tests. In addition, transportable leak-detectors are used regularly. Because of the very low temperatures used, the whole plant is, of course, heavily insulated.

High-Temperature Vacuum Furnace

GRAPHITE resistor furnaces designed to provide working temperatures up to 3000 deg. Cent. have been developed by The General Electric Company, Ltd., Magnet House, Kingsway. Typical applications include sintering, the heat treatment of metals like titanium, tantalum and zirconium, and the brazing of components for operation at very high temperatures.

Such a furnace has been installed in the B.S.A. Group Research Powder Metallurgy Laboratory at Small Heath, Birmingham. It is designed to give temperatures up to about 2000 deg. Cent., to maintain a good vacuum for the protection of a charge from oxidation, and is to be used for sintering materials for use at high temperatures.

As illustrated in Fig. 1, the body of the furnace is a water-cooled, vertical, cylindrical steel tank with a hinged, domed lid. A vacuum-tight seal is formed between flanges on the lid and the furnace body. The charge is heated by radiation from a triangular-shaped assembly of graphite bars (Fig. 2) which surrounds the charge space. These graphite bars operate at a low voltage supplied by a three-phase transformer, the secondary voltage of which is smoothly varied by a voltage regulator to give control over the heating rate. Radiation screens consisting of molybdenum sheets, arranged to enclose the heating chamber, provide the thermal insulation. With the furnace lid raised the top radiation screen can be lifted to give access to the chamber. The charge is supported on a graphite tripod.

The vacuum pumping system consists of a gas ballast pump, a combined booster and oil diffusion pump, and a valve block which controls the evacuation of the furnace chamber. The valve block is fitted with a five-position operating lever which can be moved only in one direction to ensure the right sequence of operations. With the lever in position one, air is allowed into the furnace chamber and the pumps can be switched on. In position two, the chamber pressure is reduced by the coarse pump, and this evacuation continues in lever position three (which is similar to lever position one except that air is not allowed into the chamber) until the pressure has been reduced to 0·05mm mercury. With the lever in position four, the diffusion pump continues the evacuation until the required pressure is reached. An operating vacuum between 10^{-4}mm and 10^{-5}mm mercury can be obtained. When the lever is in position five, all valves are closed so that the furnace chamber is isolated from the pumping system, and leak-rate tests can be made.

Safety devices give protection of both the furnace and the charge against possible failures in the electric and water supplies. Warning of an electric supply failure is given by an audible alarm. A fault occurring in the cooling water flow operates relays to interrupt the power supply to the furnace. An indicator lamp in each cooling circuit simplifies location of a fault.

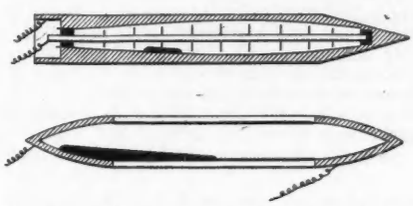
The maximum rating of the furnace is 120kVA. The furnace will take a charge approximately 9in diameter and 12in high with a maximum weight of 90 lb. With another arrangement of elements the charge space can be increased to 11in diameter by 11in high. Provision is made for introducing a hydrogen atmosphere into the furnace chamber to hasten the later stages of cooling; for example, when brazing, a 50 per cent reduction in cooling time can be obtained. Furnaces of similar design are made with loading dimensions 4in diameter by 6in high (for laboratory use) and 15in diameter by 24in high.

Inclinometers for Use in Long Underground Boreholes

TECHNIQUES of underground gasification, which are now being explored by the National Coal Board, involve the drilling of long boreholes which throughout their length must remain in a coal seam. To ensure that the hole follows the seam, some form of instrument is necessary to measure the extent to which the borehole is diverging from the horizontal, and the accompanying drawings illustrate two forms of inclinometer which have been developed for this purpose. These instruments are operated electrically, employing the system of varying the resistance of a circuit passing through the inclinometer to register changes in the inclination of the borehole in which the instrument is placed. Both of the instruments use a pellet of mercury to produce the necessary variations in the resistance of the circuit.

The inclinometer shown in the upper drawing consists of a steel tube which, internally, is cigar-shaped. Along its longitudinal axis is a rod carrying a series of electrically conducting discs, each of a diameter slightly smaller than that of the container at that point. Between each pair of discs is a high-resistance electrical path, either through the central rod, as shown, or through fine wire windings. The tube is sealed and contains a pellet of mercury sufficiently large to complete the circuit between any one of the discs and the instrument's steel shell, but not big enough to make contact with more than two of the conducting discs. As the tube is tilted, the pellet makes electrical contact to embrace a greater or lesser number of the resistance elements in the circuit, and thus changes in resistance can be calibrated as changes in inclination. Since the container is symmetrical about its centre, measurements are independent of rotational orientation and may even be carried out during rotation.

The instrument shown in the lower drawing consists of a plain tube, either of glass or other material, and either coated on the inside with an extremely thin, low-conductivity film of platinum



Two forms of inclinometers developed by the National Coal Board for determining the divergence of long boreholes from the horizontal

or having itself a low but positive conductivity. A path of higher conductivity is provided by mercury, sufficient of which is introduced to make contact from end to end of the tube when horizontal. When the tube is tilted, the resistance of the circuit is increased as the gap between the mercury and the end contact increases.

The inclinometers are of small diameter, and several inches long. They can be introduced to the point at which measurement is required by passing them up the inside of a drill rod by the water flush; after use they can be retrieved by an attached cable. When using these instruments it is only necessary to interrupt drilling for a few minutes while readings are taken.

Automatic Control for Oil-Fired Boilers

AMONG the products manufactured by James Gordon and Co., Ltd., of Dalston Gardens, Stanmore, Middlesex, are control systems for oil-fired boilers. The standard control system, which provides automatic control for boilers, both land and marine, fired with pressure atomising oil burners is well known. However, for small and medium size boilers it was considered that the relative cost of the equipment may be comparatively high, and to obviate this possible disadvantage the company has designed and is now manufacturing a simplified form of modulating control. This is the "S.D." control, which, is easy both to install and maintain in continuous

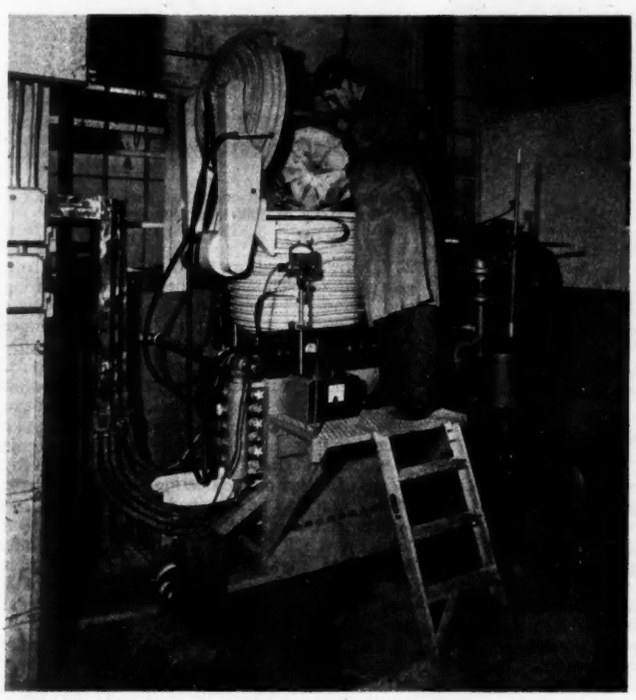


Fig. 1—High temperature vacuum furnace installed at B.S.A. powder metallurgy laboratory, Birmingham. The top radiation screen is being placed in position

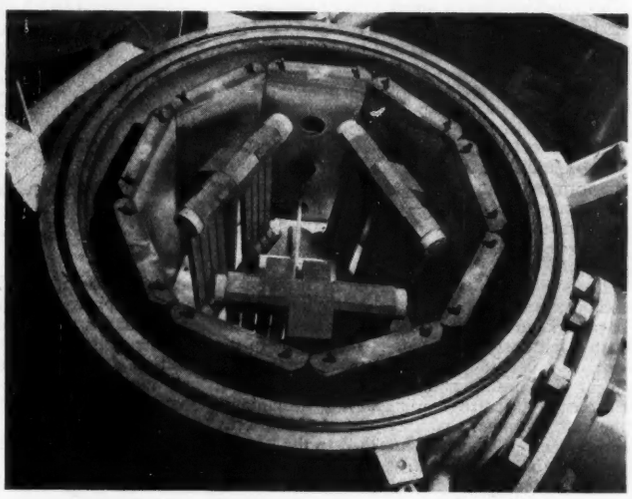
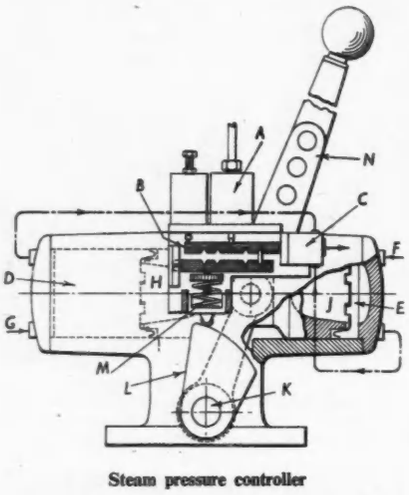


Fig. 2—Heater element assembly of graphite bars and side radiation screens of molybdenum in high temperature vacuum furnace illustrated in Fig. 1

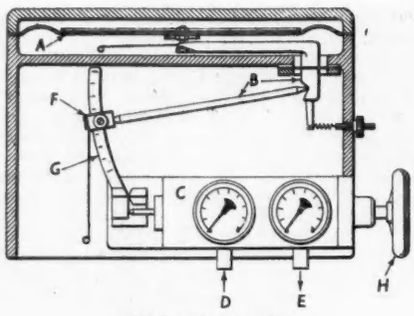
operation. It will maintain the required relationship between oil and combustion air (constant CO_2) as well as a constant steam pressure, even although the demand for steam may fluctuate widely. The steam pressure is held within narrow limits by regulating the combustion air in relation to small changes in the pressure resulting from changes in the demand for steam. Likewise, the oil supply to the burners will be regulated in relation to the air quantity, irrespective of the changes in the number of burners in use or in the load. Complete control is effected by only two pieces of apparatus, of which only one requires a power medium for its operation. The latter is the steam pressure controller, while the other piece of equipment is the air/oil ratio controller. It is possible for any maintenance required to be carried out by a mechanic, and, should it be necessary to revert temporarily to manual control, then this can be effected without having to disconnect any pipes or connecting-rods.

Our drawing shows the general arrangement of the steam pressure controller, which embodies a metal bellows, in a chamber *A*, which is sensitive to pressure variations of a few ounces per square inch, about 10 grammes per square centimetre, in the steam main to which the chamber is connected. Changes of pressure are transmitted by the bellows direct to an adjustable lever system *B* to actuate a pilot valve *C*, the movement of which causes the pressure of the power operating medium, which may be air, water or oil, at a maximum pressure of 100 lb per square inch, to build up at one end of the power cylinder while releasing the pressure at the other *D*, *E*. The operating medium is supplied to both ends of the cylinder *F*, *G*. This build up of pressure causes an adjustment in the position of the pistons *H*, *J*, and this linear movement is translated into rotary movement of the spindle *K* through the lever *N*, which is keyed on to it. This lever is positively linked to the damper of the forced draught fan so that the damper responds to any movement of the lever. Instead of controlling the air flow by means of a damper or fan inlet vanes it is also possible to do so by variation of the fan speed. Rigidly attached to the spindle *K* is the cam *L*, and any rotation of the former results in a corresponding change in position of the latter. Rotary displacement of the cam has the effect of directly adjusting the force in spring *M* to the value required to balance the force exerted by the steam pressure on the bellows in chamber *A*. Thus an increase in steam pressure will be followed by an increase in pressure in the spring and the reverse will occur with a fall in steam pressure. The profile of the cam can be cut to obtain an approximately linear relationship between the position of the piston and the corresponding air flow to eliminate the unfavourable characteristic of a butterfly air damper. The handle attached to the lever *N* provides for manual control.



Steam pressure controller

The other piece of equipment, the air/oil ratio controller, is shown in the second drawing; the duty of the diaphragm *A* is to measure the air flow to the burners, usually as a drop in pressure between the burner wind box and the combustion chamber. Deflection of the diaphragm is reflected in the movement of the lever system *B* and the force on the diaphragm is balanced, through the lever system, against the pressure of the oil supplied to the burners. Oil fuel is delivered through a port *D* to the fuel valve *C*, which adjusts the pressure as required; then the oil flows to the burners through another port *E*. Within limits it is possible to select the relationship between the air differential pressure and the oil pressure at the outlet *E* by sliding the block *F* along the curved and graduated lever *G*. For manual adjustment purposes there is a hand jack *H* which, when screwed in, opens the valves and actuates the main operating piston and thus manually controls the fuel pressure to the burners.



Air/oil ratio controller

A prototype of the new "S.D." modulating control has been fitted on board an oil tanker and normal operational tests are in course of being carried out.

Rotary Drill

A NEW rotary drill for use on coal and soft rock is now being made in two models by Atlas Copco (Great Britain), Ltd., Beresford Avenue, Wembley, Middx. The two drills are of generally similar construction, one—the "CBH 11"—having an aluminium casing and weighing 23 lb, and the other—the "CBH 11S"—having a malleable iron casing and weighing 31 lb. With working air pressures of 85 lb, 70 lb and 60 lb per square inch, the respective drill speeds are 650, 625 and 550 r.p.m., the air consumption at these pressures and speeds being 74, 65 and 51 cubic feet per minute.

Rotary drill for coal or soft rock

One of the new drills can be seen in the illustration above. It is driven by a four-vane rotary air motor, the rotor of which is carried in a hardened cylinder and end plates, and supported by two ball bearings. Drive is transmitted via a single planet reduction gearing and the drill chuck is arranged in line with the motor, enabling the drill casing to be kept to a suitable shape for ease of handling.

The drill spindle is carried in double ball bearings, and all the moving parts are totally enclosed within the casing. In order to give ease of access to the motor, a detachable cover is bolted to the rear of the casing and bosses are fitted to this cover so that, if required, fittings such as shoulder pads can be accommodated.

The trigger of the inlet throttle is placed within one of the handles of the drill, and air is supplied through a $\frac{3}{4}$in hose nipple at the underside of the drill. Air exhausts from the motor through two slots on the underside of the drill away from the operator, and the drill chuck is designed to take drill rod shanks $\frac{3}{4}$in diameter by $2\frac{3}{4}$in. The motor is lubricated with oil carried over in the air stream, whilst the gears are lubricated with prepacked grease.

Fork Lift Truck

THE rider-controlled fork lift truck shown in the accompanying illustration has just been added to the mechanical handling equipment made by Matling, Ltd., 28, Caxton Street, London, S.W.1. It has a lifting capacity of 3000 lb at 20in load centre and is available with lift heights ranging from 54in to 144in. The mast of the truck can be tilted 2 deg. forward and 10 deg. backward, and is fitted with cast steel forks which are laterally adjustable from 13in to 27in.

The truck is powered by a 24V battery which operates a heavy duty constant speed reversing motor. Transmission to the single rear wheel is through a multi-plate clutch and a three-speed gearbox. Lifting and tilting are effected hydraulically by pressure fluid supplied by a separate 24V, series wound, motor directly coupled to a gear pump which supplies pressure to the lifting and tilting jacks operating the telescopic mast assembly. The hydraulic tank is placed under the driver's seat and incorporates a pressure relief valve to prevent lifting of excessive weights.

Battery-powered rider-controlled fork truck with a capacity of 3000 lb at 20in load centre

The motor car design controls consist of a conventional steering column, with a "dead man" pedal on the right, and a foot-brake pedal on the left. A parking hand-brake is provided and the three gears are selected by means of a lever on the steering column. Reverse of any gear can be obtained by pressing a foot switch next to the dead man pedal. A green light on the facia panel shows when forward speeds are engaged and a red light indicates reverse motion. For safety purposes, a key switch must be turned and the dead man pedal actuated before the equipment can be operated. The electrical circuit is broken when the brake pedal is depressed and when the charging plug is left open. Mechanical interlocks are provided on the tilting and lifting control levers and stops inside the jacks ensure that neither load carriage nor mast can over-travel.

Industrial and Labour Notes

Employment and Defence Production

Last week, the Minister of Labour, Mr. Iain Macleod, made a statement in Parliament about the effect on employment of the Government's latest defence proposals. He explained that, as a result of the changes in policy, the volume of defence work and particularly of defence production, would be curtailed. The total expenditure on defence production and research this year was estimated at about £548 million, which, the Minister said, probably represented a fall of about one-eighth in real terms on the actual level of defence production and research in 1956–57.

Mr. Macleod went on to point out that the total volume of defence production had been declining for a number of years, and that bigger reductions in the numbers employed had been made in the past than were expected this year. In the last four years, he said, the numbers employed on defence production had been reduced by 200,000, including 70,000 last year, without causing any serious ill-effects on employment. It was probable that the reduction this year would be much less than the figure of 70,000 last year. During the next twelve months, the Minister continued, it was expected that the numbers employed in Royal Ordnance Factories might be reduced by between 5000 and 6000. In the aircraft industry about 15,000 workers who were now employed on military contracts were likely to be made available for other work within the next twelve months or so, and as a result of the reduction in Admiralty contracts a further 7000 workers would become available.

The Minister added that there might be some concern about the effects on employment if the cuts in defence production fell in areas where alternative work was not easy to find. Arrangements had been made for close co-operation between the supply departments, the Board of Trade and the Ministry of Labour, to ensure that workers released were, if necessary, absorbed in other employment as rapidly and smoothly as possible, and that where there was scope for choice in deciding where cuts should fall, the prospects of reabsorbing the workers were taken fully into account. Some workers, Mr. Macleod said, could be expected to remain at their present employment, largely depending on the extent to which the firms concerned were successful in finding civilian work to take the place of defence contracts. Where there was no alternative, however, but to make significant reductions in the size of the labour force, the longest possible notice would be given, both as regards Government establishments and private firms, so that every effort could be made to find new tenants for the factories where that was necessary, and new jobs for the workers.

Steel Industry's Expansion

An up-to-date assessment of the iron and steel industry's plans for expansion is given in the latest number of the British Iron and Steel Federation's quarterly review. The industry is planning to provide steel capacity to meet an annual estimated demand of 28,000,000 ingot tons by 1962. Blast-furnace capacity, the *Review* explains, will have to be expanded more than proportionately, as supplies of home-produced scrap will increase more slowly than the demand for steel-making materials, and more home-produced pig iron will be needed to replace imports of scrap and pig.

The expansion programme includes fourteen new blast-furnaces supported by appropriate additional coke ovens and ore preparation plants. The production of sinter is to be expanded even more rapidly, and some of the furnaces are to operate on a sinter burden of nearly 100 per cent. It is expected that the various blast-furnace projects in hand will provide an increase in capacity of 7,000,000 tons over 1956, thus making provision for 20,000,000 tons of pig iron and ferro-alloys. The *Review* goes on to say that the major part of the expansion of crude steel making will come from new plants, including eight new or greatly expanded steel melting shops and considerable extensions at a number of existing melting shops. The additional output from new capacity will be supplemented by increased output from existing plant, in particular as a result of the extended use of tonnage oxygen from new plants now under construction.

But the *Review* adds that " the provision of the necessary equipment is only the first of the industry's development problems." It is essential to ensure that the raw materials and fuel required to operate that equipment are secured and transported, that the plants are properly manned, and that the necessary investment finance is available. The steel industry fully recognises the need to use home ores as far as practicable, and between 1946 and 1956 consumption rose from 12,750,000 tons to 16,500,000 tons. That trend will undoubtedly continue, and the industry hopes to use 23,500,000 tons of home ore in 1962. But, the *Review* says, bearing in mind the time required to expand iron ore production, the trend towards working at greater depths, and the difficulty of obtaining labour for either open-cast quarrying or underground mining, it is unlikely that more than 23,000,000 or 24,000,000 tons of ore could be obtained from home sources by that date. The increasing reliance of the British steel industry on foreign ores may involve a total import of some 22,000,000 to 24,000,000 tons by 1962, compared with 14,000,000 tons last year. At the same time, Continental and American steel makers will also wish to import increasing tonnages of ore.

Although existing sources of supply will probably cover more than half the additional European ore requirements, the remainder will have to come from new fields. The British steel industry's central ore importing agency has been exploring the potentialities of new fields ranging from the Equator to the Arctic Circle, and it is believed that the additional ore needed can be obtained. The steel industry is pursuing a policy of securing future supplies by means of long-term contracts, and is also engaging in direct financial participation in certain ore developments overseas.

Labour Relations

Before the House of Commons adjourned for the Easter recess on Thursday of last week, there was a debate on labour relations. The subject was introduced by Mr. A. E. Cooper, who emphasised at the outset that our record of " industrial difficulties " was much better than that of any other country. But, he pointed out that strikes were of greater seriousness to this country because its economy was so finely balanced. Given good management and proper labour relations, combined with effective Government budgetary and monetary policies, Mr. Cooper said, no possibility of unemployment in this country within the foreseeable future was possible. He suggested that a long-term contract, linking any increases in pay to the cost of living and to increased productivity, should form part of the pattern of British industry. Mr. Cooper went on to express the view that the most important aspect of the present situation was " nation-wide bargaining." Taking the engineering industry as an example, he argued that it was unreal to expect a confederation of unions to negotiate arrangements which would work properly and equitably amongst 20,000 firms engaged in an industry. Mr. Cooper urged that the Government should consider setting up a select committee which could examine the whole question of labour relations.

The Parliamentary Secretary to the Ministry of Labour, Mr. Robert Carr, replied to various points raised during the debate. He said that, since the war, there had been attempts to do in this country what had never been done before, namely, to achieve at one and the same time a combination of full employment, free collective bargaining as the method of fixing wages, and stability in the value of money. It was comparatively easy to have any two of those three things at the same time, but it was extremely difficult to have all three of them at once. In practice, Mr. Carr commented, we had succeeded in keeping full employment and free collective bargaining, but it had to be admitted that we had not achieved stability in the value of our money. About the " concern " which many people were feeling at present, Mr. Carr expressed the opinion that, in the second half of this twentieth century, we ought to be able to settle disputes peacefully and by negotiation, without resort to strikes and lockouts, which usually resulted in loss to everyone and which must, in the end, be settled by agreement. Then, he added, there was growing dismay about our apparent inability to escape from the wage price spiral, under which those who had increases in wages only benefited in real terms for a short time, whilst other members of the community were actually made worse off. Furthermore, there was a growing feeling that a way must be found of containing wage increases within the bounds of extra production and efficiency, so that the real value of wage increases was maintained for those who got them, prices remained stable, and no damage was done to other sections of the community.

Mr. Carr went on to refer to the progress of the inquiry, which was initiated last year by the National Joint Advisory Council, into the efficient use of manpower. He ended his speech by saying that whatever inquiries were made and whatever changes might be instituted in the machinery or in the scope of agreement, the real way to progress was in the growth of good relations and good practices in each individual factory.

The Australian Copper Industry

(*Contributed*)

COPPER has been mined in Australia continuously for the past 112 years. From the 1840s until to-day total mine output has been 1,800,000 tons of metallic copper, principally from South Australia, Queensland, New South Wales and Tasmania. A little copper has been obtained from Western Australia, but practically none from Victoria. The Northern Territory is producing a relatively smaller quantity from the Peko Mine and has possibilities for greater output in the near future. An appreciable quantity of copper, something like 2500 tons, is produced each year as a by-product of lead-zinc mining at Broken Hill and at Rosebery in Tasmania. Many of the famous mines have long been defunct, and to-day the Mount Isa mine in Queensland, with 25,000 tons annual output, is the outstanding producer, followed by Mount Lyell, in Tasmania, with 8500 tons, then Mount Morgan, in Queensland, with 7000 tons, and a few minor contributors helping to swell the total. The peak production of 46,500 tons for Australia as a whole was reached just before the first world war. Subsequently there was a decline to 8700 tons in the mid-twenties, then an increase in the second world war period, and recently a return to the 45,000 tons level largely through the increased output from Mount Isa and Peko. Total output from the mines at present is about 1·7 per cent of world mine production. Provided that the price of copper remains favourable, the total output could rise to well above 60,000 tons in a few years.

Until the early part of this century smelting and refining had been carried out at various centres by old-established furnacing methods. But in 1909 electrolytic refining was commenced at Port Kembla, N.S.W., by the Electrolytic Refining and Smelting Company of Australia Pty., Ltd. (known as the "E.R. and S."), mainly to treat the gold-bearing copper from Mount Morgan and, later, the copper from Mount Lyell and other places. The supply was adequate for Australian needs until the second world war, when production of munitions necessitated importation of a large quantity of copper—the first of note in Australia's history. Importation since the critical war years to augment domestic supplies has amounted to more than 250,000 tons, valued at many millions of pounds. This imported copper has been mainly in the form of wire bars, blister (partly refined copper), ingots and rolled rod, with smaller quantities of billets, cakes and cathodes. Refining by the electrolytic process, which was developed in the latter half of last century, is peculiar to the non-ferrous metals industry, especially to copper and zinc. To-day 80 per cent of world output of primary copper is of electrolytic quality. Present electrolytic refining capacity in Australia (the E.R. and S. Co. and Mount Lyell combined) is about 40,000 tons of cathodes a year, and present casting capacity (the E.R. and S. Co. only) is nearly 70,000 tons of shapes a year. Actual production has never reached these levels, as it has been dependent upon the availability of copper from domestic mines.

The Fabricators.—Until the first world war the production of manufactured, semi-manufactured or fabricated copper was negligible, practically all requirements for rod, wire, strand, plate, sheet, strip and sections being satisfied by importation, principally from the United Kingdom. A shortage of copper telephone wire during the war, however, prompted the Commonwealth Government to ask Australian copper producers about the practicability of rolling and drawing copper in Australia. This led to the formation in 1916 of Metal Manufactures, Ltd. Metal Manufactures, Ltd., has for long been the largest fabricator of copper products in Australia, its output last year exceeding 43,000 tons, containing about 40,000 tons of copper. The parent works, which covers 35 acres and employs 1700 people, is situated close to the harbour of Port Kembla, within a mile or two of the works of Australian Iron and Steel, Ltd. It is fully equipped for making a wide range of copper, copper alloy and aluminium wire, strand and tubes. Considering the existence of several Broken Hill mining companies and the manner in which the iron and steel industry in Australia is centred in the Broken Hill Proprietary Company, Ltd., it is important to appreciate the fact that the B.H.P. Company, Ltd., has no connection with the Electrolytic Refining and Smelting Company, Metal Manufactures, Ltd., or any other copper refining or fabricating firm. In Australia the iron and steel and the copper industries are entirely distinct branches of the metal industry, financially and otherwise. Several years before Metal Manufactures, Ltd., was established another metal company was formed in a small way in Sydney to engage in smelting and casting non-ferrous metals and alloys and, later, to produce rolled copper and copper alloy rod. It commenced operations at Alexandria, N.S.W., in 1914 under the name of Austral Bronze Company. After minor changes in name and location it gradually expanded and succeeded in establishing itself as the principal producer in Australia of rolled copper and copper alloy plate, sheet and strip, and extruded rods and sections. In 1929 the whole of the share capital of this company was acquired by Metal Manufactures, Ltd., and from then on the two companies were able to develop as suppliers of as wide a range of fabricated copper and copper alloy products as is economically possible in the country. At the end of the war Austral Bronze expanded still further by acquiring from the Commonwealth Government a works at Derwent Park, Tasmania, where it now produces copper, bronze, brass and nickel silver strip. Cathode copper for melting and casting there is obtained direct from the Mount Lyell refinery on Tasmania's West Coast. Nor would a description of the Australian copper industry be complete without mention of the Commonwealth Government's ammunition factory at Footscray, Victoria, which is fully equipped for rolling copper, brass and other alloy strip for small arms and gun ammunition, and other components of munitions.

The Cable Factories.—It has long been the custom for producers of copper wire to engage in the production of insulated conductors—a natural step to take with copper, since wire forms such a large portion of the total output of copper products (between 30 and 40 per cent). The Australian copper industry has been no exception to this custom. For years Metal Manufactures, as the only producer of rolled copper rod, and the principal drawer of copper wire, has supplied wire, and recently rod as well as wire, to various cable makers in New South Wales and Victoria. Early in its history it pioneered the manufacture of paper-insulated lead-covered telephone cable at Port Kembla, but withdrew from direct participation in this field when a new company, named Austral Standard Cables Pty., Ltd., was formed in 1947 to specialise in the manufacture of telephone and other types of telecommunication cables. The new company continued manufacturing with existing plant at Port Kembla and also completed the erection of a new factory which had been commenced by Metal Manufactures close to its branch wire and tube factory at Maribyrnong. This factory is now the manufacturing headquarters of Austral Cables Pty., Ltd. Some years before the formation of Austral Standard Cables, the production of rubber-insulated flexibles and cables had been started in New South Wales by a new company named Cable Makers Australia Pty., Ltd. The works of this company at Liverpool obtain partly drawn wire from Port Kembla, and further cold drawing to a range of sizes for covering with rubber or plastic is done at Liverpool. Shortly after these events still another company, named British Australian Power Cables Pty., Ltd., was formed to complete the range of manufacture of commercial insulated conductors. This factory is situated at Port Kembla, close to Metal Manufactures, from which it obtains its copper wire. The finished product is paper-insulated lead-covered power cable for use up to 22,000 volts. No redrawing is done by this company. In Victoria there are several independent firms of cable makers, which rely on either the Port Kembla or the Maribyrnong works of Metal Manufactures for supplies of rod or wire.

Other Activities.—Copper and brass sheet, strip, tubing and extruded sections are not, as a rule, processed further by the large fabricators to metallic articles for final use, although there are examples of this kind of integration in Australia. All copper and brass tubing is sold straight from the drawbenches, and is not "fabricated" or "manipulated." Other activities include the production of copper alloy castings, mainly brasses of various types, and the services rendered to the castings trade and minor fabricators by the ingoting firms, which collect scrap and run it down to ingots of approved quality. A good deal of copper scrap is handled by the refinery at Port Kembla, and much high-grade process scrap is kept in circulation by the large fabricators.

Comparisons with Steel.—If a broad view is taken, many resemblances can be found between the copper and the iron and steel industries for the reason that both copper and iron are easily reduced from their ores, and when refined are amenable to hot and cold working. In smelting and refining many comparisons can be made, despite differences in the nature of the ores (mainly sulphides in one case and oxides in the other) and the shapes and sizes of furnaces used. In hot and cold rolling close parallels exist between what is done at Austral Bronze and Crane Copper and Aluminium, on the one hand, and the B.H.P. Company, Ltd., A.I. and S., Ltd., Lysaghts and Commonwealth Steel Company, Ltd., on the other. It can be regarded as a detail that between 30 and 40 per cent of total copper products is in the form of wire, and between 40 and 50 per cent of steel products is in the form of plate, sheet and strip: this is because copper is a good conductor of electricity and steel is eminently suitable for structural purposes.

There are, of course, some vitally important distinctions that deserve mention. The first is mining, where the advantages are incomparably on the side of iron (compare the easily-won ore containing more than 60 per cent iron at Iron Monarch in South Australia with the 0·6 to 0·7 per cent copper ore at Mount Lyell, in Tasmania). Another is that electrolytic refining and extrusion—a method of producing rods, sections and tubes in presses operated by hydraulic power—are characteristic of the copper industry. Extrusion is widely used in copper, aluminium and lead industries, but is not to be seen at all in the Australian steel industry. Even more striking is the absence from the copper industry of coking and the concomitant use of by-product gas as fuel. It may be assumed that the coking side of iron and steel manufacture will never have its counterpart in the copper industry as we know it to-day. Not that coke is unnecessary in copper smelting; on the contrary, either coke or coal is essential in the reduction of copper from its ores in blast or reverberatory matting furnaces, but not in such large quantities as to make desirable the working of coal mines by owners of copper mines and smelters. Another important distinction is that, in the iron and steel industry at Port Kembla and Newcastle, and elsewhere in the world, integration is developed to the point where blast-furnaces, open-hearth furnaces, and rolling mills are stages in the flow of operations controlled by one company at one works. Rarely does one find rolling mills in the copper industry run in conjunction with smelting and refining at one site. Lastly, with regard to transport, which figures so largely in the B.H.P. Company's operations, the relatively small output of the Australian copper industry, of some 70,000 to 80,000 tons of fabricated and cast products annually, does not require the smelters or the fabricators to own a line of ships in order to move raw materials and finished products from State to State.

European Atomic Community

ON March 25, the treaty for the establishment of a European Common Market and a European Atomic Community (EURATOM) was signed in Rome. The treaty, which is subject to ratification by the Parliaments of the signatories (Belgium, France, Germany, Italy, Luxembourg and the Netherlands), marks a further step in the progress of the countries of the European Coal and Steel Community towards integration.

As regards EURATOM, the function of the Community will be, by creating the conditions required for the speedy formation and development of nuclear industries, to help to raise the standard of living in the Member States and to promote trade with other countries.

The tasks entrusted to the Community will devolve upon four institutions, viz. the Assembly, the Council, the Commission, and the Court of Justice.

Members of the Assembly are to be appointed by the various Parliaments in the following proportions :—

Belgium	14
France	36
Germany	36
Italy	36
Luxembourg	6
Netherlands	14
Total	142

A scheme for holding elections by direct universal suffrage is to be considered by the Assembly.

The Assembly will meet in ordinary session once a year (in October) in order to discuss the annual general report of the Commission, and may, if necessary, meet in extraordinary session.

The Council is to be composed of one representative from the Government of each Member State, and will be responsible for co-ordinating the action of these States and of the Community. Unless otherwise provided for, decisions of the Council will be taken by the vote of a majority of the members composing it, the votes being weighted as follows :—

Belgium	2
France	4
Germany	4
Italy	4
Luxembourg	1
Netherlands	2
	17

Decisions of the Council will be deemed to be adopted if supported by twelve votes in the case of a proposal submitted by the Commission, and twelve votes cast by at least four members in other cases. A decision, adopted on the proposal of the Commission, may only be amended by a unanimous vote.

The Commission will supervise the application of the Treaty ; formulate recommendations and opinions on matters falling within the Treaty's purview ; exercise its own power of decision and take part in the formation of Council and Assembly decisions, and exercise the powers vested in it by the Council.

It is composed of five members, of different nationalities, appointed by the Governments for a term of four years, who may be reappointed and who will be completely independent in the exercise of their functions and may not solicit nor accept instructions from Governments. Decisions will be adopted by a majority of the members. The Commission will have the assistance of an advisory body, the Scientific and Technical Committee, consisting of twenty members appointed for a five-year term by the Council after consulting the Commission. The Council and the Commission will be assisted by an Economic and Social Committee with advisory powers, whose members will be appointed for a term of four years, and may be re-elected.

The Court of Justice is to consist of seven judges and two advocates-general, who will be appointed for six years by the Governments and who may be reappointed. The Court of Justice may be appealed to by the Commission or the Member States if any of the latter has failed to fulfil its obligations. It will be the purpose of the Court of Justice to watch over the legality of binding decisions of the Council and the Commission. Any individual or corporate body may similarly appeal against decisions directed against or affecting it.

Objectives of EURATOM

The Commission is to promote research. Research and training programmes, which may not exceed five years, will be fixed upon by a unanimous decision of the Council taken on the proposal of the Commission.

A Nuclear Research Centre is to be set up which will be responsible for standardising nuclear terminology and measurements, and will make available the services of a central nuclear measurements bureau. It is intended to set up an institution of university standing for the training of nuclear specialists, to organise and develop the exchange of knowledge and information, and to co-ordinate the research conducted in Member States.

The Commission will be empowered, among other things, to conclude research contracts with Member States, persons or undertakings, as well as with international organisations or nationals of other states, and to contribute financial and technical assistance to research.

Dissemination of Information

The Commission is to obtain licences to exploit patents covering inventions of use to the Community. These are to be made available on request to Member States, persons and enterprises, provided they are in a position to exploit them effectively. The granting of a licence implies compensation and, where necessary, the right to grant sub-licences to third parties and the obligation to treat the inventions in question as trade secrets.

Member States shall be bound, on their own initiative or at the Commission's request, to notify the Commission of the applications for patents or working models for a specifically nuclear object which have been lodged with them. The same is to apply in the case of patents or working models, which, without being specifically nuclear, are directly connected with or essential to the development of nuclear energy in the Community. These communications will be confidential, and the inventions may be used only with the consent of the applicant or after arbitration or compulsory proceedings have been taken. An Arbitration Committee will be set up by the Council on the proposal of the Court of Justice.

Information obtained by the Community as a result of the execution of its research programme, the disclosure of which might be detrimental to the defence interests of one or more Member States, is to be classified as confidential.

Basic standards concerning the personal safety of the population and workers against the dangers resulting from ionising radiation will be established in the Community. The standards will fix the maximum permissible doses of radiation, the maximum permissible exposure and contamination, and the fundamental principles of medical supervision of workers. The Commission will set up, within the framework of the Community Nuclear Research Centre, an information and study centre for personal safety problems.

The Commission will publish programmes indicating the production aims for nuclear energy and the required capital investment. The Commission, as well as the Government concerned, will be notified of projected investments, it being the duty of the Council of Ministers to define the nature and importance of the projects communicated.

Community enterprises will be deemed to be enterprises which are of outstanding importance for the development of nuclear industry in the Community and which the Council of Ministers will decide to set up after investigation by the Commission. Their statutes and rules of operation will be governed by special provisions.

Supplies

The supply of ores, raw materials and fissile matter will be ensured on the principle of equal access to resources, and by pursuing a joint policy of supply.

For this purpose, the Commission will set up a Commercial Agency, which will be a corporate body vested with financial independence and will possess an option to purchase ores, raw materials and special fissile matter produced in the territories of the Member States, and the exclusive right to conclude contracts for purchase or sale outside the Community.

The Commission may make recommendations for promoting the prospection and exploitation of mines ; it may assume financial participation ; it will receive from Member States annual reports on prospecting, reserves, and mining investments.

The Agency may build up commercial stocks for facilitating current deliveries, while the Commission may, if necessary, decide to form reserve stocks.

The Commission will give its advance agreement to the conventions concluded with other states for deliveries of products.

It may exempt from the following provisions movements of products used for research purposes and such products as are partly processed and must therefore go back to the enterprise of origin.

The Agency must, however, be notified.

Resources Within the Community.—The Agency's option of purchase of ores, raw materials and special fissile matter will be exercised through contracts concluded with the producers. Equal access of consumers to internal resources will be guaranteed by the communication to all users of the applications and offers received by the Agency, and by the conclusion of a contract between the Agency and the user. The Agency must satisfy all the applications received, of, if unable to do so, distribute the supplies in proportion to the orders corresponding to each of the offers.

If the Agency has not exercised, in whole or in part, its option of purchase in respect of a producer, the latter will be authorised by the Commission to dispose of the surplus of his production outside the Community at a price which may not be less than that of the offer previously made to the Agency.

Special fissile matter, however, may only be exported through the Agency.

Resources Outside the Community.—The Agency has the exclusive right to conclude contracts for supplies from third countries. If, however, the Agency places at the disposal of users supplies at excessive prices or is not in a position to deliver all or some of the required supplies within a reasonable time, the consumers will have the right to conclude direct contracts for supplies from third countries, after due notification to the Commission.

Prices.—Prices will be regulated by the interplay of supply and demand, all consumers being entitled to similar conditions. The Member States may not infringe this rule through national legislation. With regard to official price fixing, this may only be instituted by a unanimous decision of the Council of Ministers taken on a proposal of the Commission. Price adjustments designed exclusively to give certain consumers a monopoly will be prohibited. In the case of disputed transactions, the Commission may restore the prices to a level compatible with the principle of equal access. It may propose to consumers a standardisation of prices.

Amendments.—The foregoing provisions may be amended, more particularly in cases where unforeseen circumstances produce a general shortage, on the initiative of a Member State or of the Commission, by the Council taking a

unanimous decision on the proposal of the Commission after consulting the Assembly.

Security

The Commission must ensure that ores, raw materials and special fissile matter are not diverted from their intended use as declared by their consumers; and that the arrangements for their supply and any special control measures accepted by the Community in an agreement concluded with a third State or an international organisation are observed. To this end the Commission will receive from enterprises a declaration showing the basic technical characteristics of their plant; it will require statements of transactions in order to facilitate accounting of ores, raw materials and special fissile matter. These returns will be communicated by the parties concerned to the Member States. The Commission may insist on all surplus special fissile matter temporarily not in use being placed in deposit, and will arrange for its inspectors to carry out checks and, where necessary, impose sanctions which range from a warning to complete withdrawal of raw material or special fissile matter.

Special Fissile Materials

Special fissile materials will be the property of the Community. The Community's right of property will extend to all special fissile matter produced or imported by a Member State, an individual or an enterprise, which are subject to security control regulations.

Member States, individuals or enterprises will be entitled to the widest possible utilisation and consumption of the special fissile matter which has legitimately come into their possession, subject to the obligations arising from the provisions of the Treaty.

The Agency will, on behalf of the Community, keep a special account entitled "Financial Account for Special Fissile Matter." Changes in value will not involve the Community in any profit or loss.

Common Market in Nuclear Materials

The common market in nuclear materials will seek to repeal import and export duties or taxes on Treaty products. (The non-European territories of Member States may continue to levy duties or taxes solely of a fiscal character.) A common tariff will be applied to third countries; the free movement of persons engaged in nuclear work is to be facilitated. An insurance scheme is to be set up against atomic risks; the transfer of capital needed for nuclear projects is to be facilitated.

External Relations

The Commission will be responsible for any liaison needed with the various international organisations, and may, with the approval of the Council of Ministers, conclude agreements with third States and with international organisations. Member States will notify the Commission of the clauses of agreements and arrangements concluded or to be concluded with third States which fall within the scope of the Treaty. The Commission will examine their compatibility with the Treaty and may, if necessary, bring the matter before the Court of Justice.

Financial and General Provisions

Estimates.—Estimates of all the Community's revenue and expenditure, other than those of the Agency and the joint enterprises, must be drawn up for each financial year (January 1 to December 31), and must be entered either in the operational budget or in the research and investment budget.

The revenue and expenditure of the Agency, which will operate on commercial lines, will be estimated separately.

The estimates of revenue and expenditure, together with the working accounts and balance sheets of the joint enterprises for each financial year, will be communicated to the Commission, the Council and the Assembly, in the manner as laid down by the statutes of these enterprises.

Resources.—Receipts of the operational and research and investments budgets will be composed, apart from other current receipts, of the financial contributions of Member States fixed in accordance with the following proportionate scale :—

	Operational, per cent	Research and investment, per cent
Belgium	7·9	9·9
France	28	30
Germany	28	30
Italy	28	23
Luxembourg	0·2	0·2
Netherlands	7·9	6·9
	100·0	100·0

Overseas Territories.—Unless otherwise provided for, the provisions of the Treaty will apply to the European territories of the Member States and to the non-European territories under their jurisdiction. They will also apply to the European territories for the foreign relations of which a Member State is responsible.

Extension of Powers.—If action by the Community appears to be necessary in order to achieve one of the Community's objectives, although no provision has been made in the Treaty to exercise the powers of action thus required, the Council, by a unanimous decision on a proposal by the Commission and after consulting the Assembly, will take the appropriate measures.

Amendment of the Treaty.—The Government of any Member State and the Commission may submit to the Council proposals for amending the Treaty. For this purpose, a conference of the representatives of the Governments of Member States, will be convened. The amendments will come into force after they have been ratified by all the Member States.

Admission of New Members to the Community.—Any European State may apply to become a Member of the Community. It will send its application to the Council, which, after consulting the Commission, will take a decision by a unanimous vote.

The conditions of admission and the consequential changes to be made in the Treaty will form the object of an agreement between the Member States and the applicant State. This accord must be ratified by all the contracting States in accordance with their national constitutions.

Tube-Straightening Machine

We have received details of the "Model WRUA" tube-straightening machine, which is built by Th. Kieserling and Albrecht, Solingen, German Federal Republic, and handled in this country by F. W. Kubach, 12, Sylvan Road, London, S.E.19. Our accompanying illustration shows the machine, which is designed for welded or seamless black tubes of ¼in to 2½in diameter, and straightening speeds up to 300m per minute. The main motor is of 68 h.p., and the drive is either by means of a d.c. motor or through a nine-speed gearbox.

For any given size of tube, the rolls can be vertically adjusted by means of the push-button controls or the square-headed shafts seen on the front of the machine at the top. Angular adjustment of the top and bottom rolls is made by turning the square-headed shafts at the infeed end.

Loading is completely automatic, by means of a roller conveyor and infeed guide channel with power-driven rollers. After the straightening operation, which proceeds without break, the tubes are deposited by the unloading mechanism shown on the left, which is controlled by a limit switch actuated by the tubes themselves.

Electric Cable for Remote Control

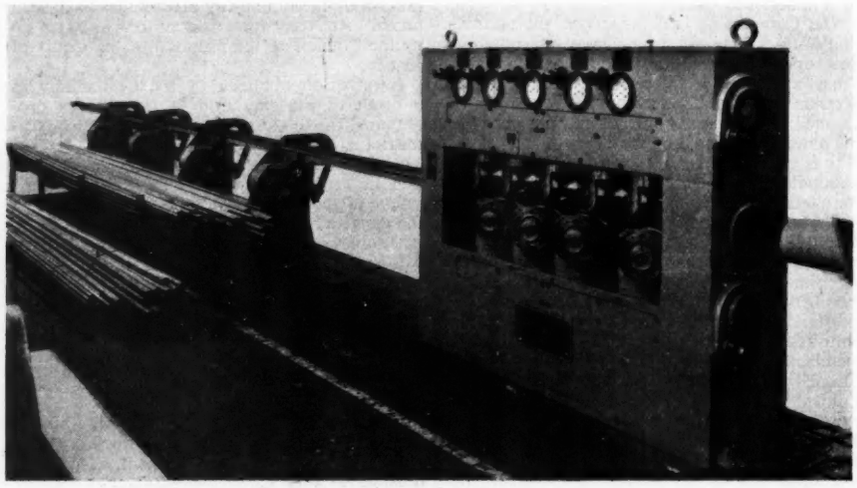
It is often desired to have available, over an extended length of working space, the means of stopping a machine in case of emergency or accident. Until recently, this could in general only be achieved by having a large number of stop-buttons arranged in parallel and distributed as required.

The Cable Division of Forges et Ateliers de Constructions Electriques de Jeumont, Jeumont (Nord), has developed a special remote-control cable—invented by a French mining engineer—comprising a flexible sleeve supporting internally two flat strip conductors which are arranged in the form of two helices with a spacing of half a pitch relative to each other. Contact between the conductors is made by compressing the cable. In this way, for instance, a no-volt coil may be shorted out by means of a relay and a motor stopped. On releasing the pressure the strips assume their former shape and the contact is again broken. The maker states that this offers a convenient method for stopping coal-mine conveyors, conveyor belts, or other devices which extend for a distance from the driving motors.

While it is undoubtedly possible in confined situations to cause unintentional stoppages, the benefits to safety of having available in such conditions a very reliable continuous means of emergency shut-down are thought to outweigh any such disadvantages.

Nuclear Marine Propulsion

It has been announced that a study and design group for atomic marine propulsion has been formed by four French companies. They are Ateliers et Chantiers de France, Chantiers de l'Atlantique (Penhoët-Loire), Forges et Ateliers du Creusot (Schneider), and Forges et Chantiers de la Mediterranée. The pool is to be known as "Propatome" and aims at co-ordinating all technical facilities possessed by the four establishments for the design and manufacture of nuclear marine propulsion plant. It will work in close co-operation with other organisations and committees whose assistance may prove useful, in particular the already existing France Atome Association, three of whose shareholders are among the "Propatome" founders.



Straightening machine for ¼in to 2½in diameter tubes, at speeds up to 300m per minute

Experimental Boiling Water Reactor at the Argonne National Laboratory

BY OUR AMERICAN EDITOR

No. II—(*Continued from page* 625, *April* 19)

The experimental boiling water reactor (EBWR) at the Argonne National Laboratory, of Lemont, Illinois, was officially dedicated and went on the line in February, 1957. It is the first unit within the power reactor programme of the U.S. Atomic Energy Commission to be completed. The pile produces 20MW of heat, which, in turn, is used to generate 5MW of electricity for consumption at Lemont. The relatively small plant is mainly intended to study and to demonstrate the practicality of direct-cycle boiling water reactors for power generation. Initially, ordinary water is used, but it is planned to change to heavy water in the future.

Shielding and Insulation

THE reactor shielding was designed to meet the requirements for operation with a 40MW heavy water core. As such it is more than adequate for the present reactor. In addition to the shielding afforded by the water and the vessel walls, the vessel is surrounded by a 3in thickness of stainless steel wool insulation, 3in of air space, and a cylindrical steel tank which serves as an inner form for shielding. This tank is equipped with cooling coils on its outer side to remove the heat transferred to and generated within the shielding. The coils are covered with lead brick and with a plaster containing ferro-boron as part of the fine aggregate. The remainder of the space between the plaster and the wall of the octagonal shell is filled with either magnetite concrete with steel punchings added, magnetite concrete, or ordinary concrete, depending upon the radiation intensity at the point concerned. The total thickness of radial shielding is 8ft 3½in.

The shielding below the reactor vessel is essentially magnetite concrete with steel punchings added. At the top of the reactor, shielding is provided by a stainless steel indexing plug assembly within the vessel, the top cover of the vessel, and a portable water tank which also effects the top seal of the air envelope surrounding the reactor. The spaces surrounding the vessel support lugs and top closure are filled with specially shaped magnetite concrete blocks, steel plates, and a container filled with lead pellets.

Auxiliary Control

Auxiliary emergency shut-down control for the reactor is provided in the form of a high-pressure and low-pressure boric acid injection system. In the high-pressure system, 160 gallons of saturated boric acid solution are maintained under 1600 lb per square inch gauge air pressure in a tank and are injected into the bottom of the reactor vessel in the event of failure of the control rod system. The low-pressure system is used only when the reactor pressure is reduced to less than 20 lb per square inch gauge, and the water level is low. The boric acid solution is introduced into the top of the vessel at a distribution ring equipped with spray arranged to ensure the impingement of the solution on all exposed parts of the core for the purpose of removing the heat caused by radiations from the fission products in the uranium. This heating occurs even after the reactor has shut down, and still amounts to 1 per cent of the normal power level seven hours after shut-down. Here the boric acid is present only to maintain sub-criticality with water addition.

Reactor Steam System

The EBWR is a complete direct-cycle boiling water reactor power plant producing about 5MW of electricity from 20MW of reactor heat in the form of steam at 600 lb per square inch gauge. This electricity is fed into the laboratory distribution system. Power generation itself is not a primary objective in the EBWR plant, since the feasibility of generating electricity with pressurised steam requires no verification. However, many of the questions on which more information is needed are associated with the direct coupling between the reactor and the power generating equipment ; hence the need for a complete power plant. Prominent among these uncertainties are radioactivity and reactivity feedback effects. Corrosion, erosion, leakage and water quality control must also be studied in an integrated system.

The properties of steam generated in a nuclear reactor differ from those of ordinary steam in two respects which affect the power plant design. Reactor steam is slightly more corrosive because small amounts of water are dissociated into hydrogen and oxygen and the free elements make the water more corrosive. The corrosion and erosion particles become radioactive as they pass through the reactor core and some of the particles will be carried over with the steam. In the future, when heavy water is used, the monetary value of the heavy water itself will make the conservation of even minute quantities of steam and water significant.

The general EBWR steam system is shown in the flow diagram reproduced herewith. In the power plant, saturated steam at 600 lb per square inch gauge and 488 deg. Fah. is passed from the reactor vessel to the turbine through a steam drier. The steam drier is equipped with cooling coils and may also serve as an emergency cooler. Measuring 36in in diameter, the vessel is made of solid austenitic stainless steel of A.I.S.I. type 304, with a 1 $\frac{5}{16}$in wall and an overall straight section of 5ft 11½in. The horizontal vessels use two rows of conventional scrubbers similar to steam separating equipment employed in steam boilers. In addition to normal operation at 61,000 lb per hour at 600 lb per square inch gauge, low-pressure operation and transient conditions also had to be considered. In normal operation, the steam leaving the reactor would contain approximately 1 per cent moisture, which is reduced to 0·1 per cent and the solids in the steam are reduced to less than 0·001 p.p.m.

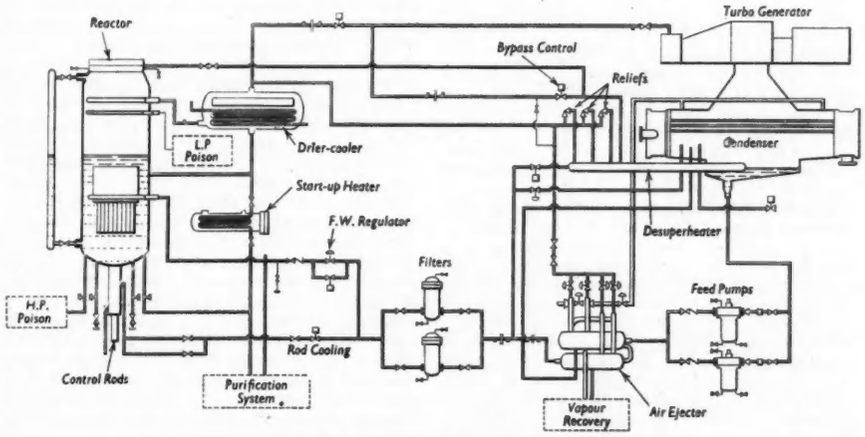
To achieve economy, it was decided to combine in the same steam separator vessel a stainless steel cooling coil for use in emergency heat absorption. After a reactor shut-down, for example, the decay of fission products will continue to generate a considerable amount of steam which normally would be condensed in the main turbine condenser. In an emergency, the cooling coils will remove this heat. A 15,000-gallon tank in the top of the building supplies a 50ft head of cooling water which will flow by natural circulation to the cooling coils in the steam drier. Steam in excess of that demanded by the turbine in response to generator load is by-passed through a desuperheater directly to a condenser. This by-pass system maintains a constant pressure in the reactor vessel. In addition, three steam system relief and safety valves discharge into the desuperheater. The complete containment of the steam, even that from relief and safety valves, is a distinctive aspect of the EBWR. Vacuum is maintained in the condenser by an air ejector system which is fed by steam from the drier. The turbine discharges steam directly to the condenser.

Water purity is maintained by ion exchangers and filters. Water is removed from the bottom of the reactor vessel, passed through the ion exchangers and returned with the feed water. A vapour recovery system collects any water vapour carried over by the air ejectors and any leakage through the seals of the turbine, pumps and valves. This water is returned to the condenser. The vapour recovery system is now used to prevent radioactive contamination ; it will also have economic value when heavy water is used.

Turbo-Generator

The turbo-generator is a 5MW, 3600 r.p.m. Allis-Chalmers machine designed for throttle conditions of 560 lb per square inch gauge and 482 deg. Fah. The particular requirements of the EBWR cycle called for a low-temperature turbine of exceptional tightness. The turbine is a multi-stage (one Curtis and eleven Rateau stages) impulse unit solidly coupled to the generator and direct-connected exciter. Unlike normal turbines built for these steam conditions, the entire turbine casing is of cast steel with the steam chest cast integrally with the steam end casing. The turbine rotor is a forged steel shaft with shrunk-on forged steel bucket shells. The trip and throttle valve assembly is welded directly to the turbine steam inlet. Ample strainers are situated in both the steam and oil circuits to prevent any possibility of damage from extraneous material in the system. The metallurgical requirements did not pose any serious problems, although some compromises had to be made in the use of less desirable alloys from the radiation viewpoint in order to obtain the erosion resistance needed under saturated steam operation.

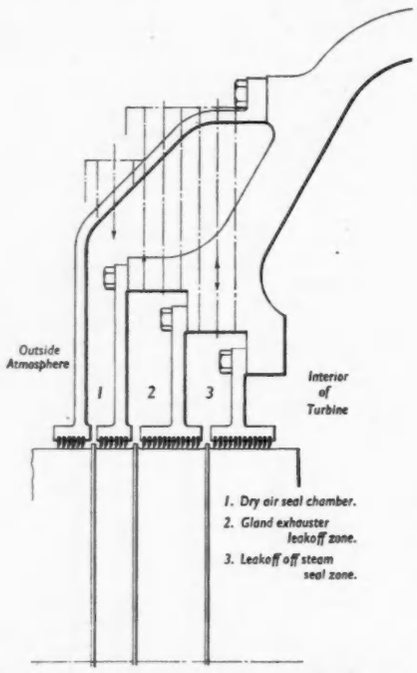
Erosion in the exhaust stages is held to a minimum in spite of the high moisture content of the steam by moisture deflection lips on the diaphragm faces of the last two stages. These lips protect the casing from erosion and conduct trapped moisture down to the individual inter-stage drains at the bottom of the turbine. Three



Steam and water flow diagram of EBWR nuclear power station

of these drains bleed off water directly into the exhaust casing. The leading edge of each bucket in the last stage is faced with a section of Stellite to reduce erosion. Because of the frequent shut-down schedule expected with experimental operation and because of the remote operation requirement, the unit includes a turning gear which turns the rotor at 3 r.p.m. during shut-down, minimising any possibility of distortion in the rotor or casing.

The use of turbine labyrinth shaft seals at each end of the casing is unique to the EBWR turbine, although the basic principle has been used on other equipment built by Allis-Chalmers where leak tightness is demanded. Because of the pressure and temperature range, speed, shaft expansion and other factors it was not considered practical to seal off completely all leakage around the turbine shaft. A sealing gland was designed that would reduce leakage to a minimum and then eliminate any undesirable effects of the remaining leakage. Leakage in either direction



Special three-fold shaft seal design used on the Allis-Chalmers steam turbine for the EBWR station

is undesirable because of radioactivity in the steam and because the "light" water content of ambient air would dilute the "heavy" water in the EBWR cycle under future heavy water operation. The seal consists of a series of spring-backed baffle rings having an inner diameter just slightly greater than the rotor shaft diameter. Steam under a pressure of ½ lb to 2 lb per square inch gauge is supplied to the inner chamber by the main gland steam manifold. A vacuum of 6in of water is supplied to the second chamber. Drainage into this chamber is piped to the reactor water recovery and air drying (RWR–AD) system, which also produces the 6in vacuum. The outer chamber is supplied with a pressure of 6in of water of dry air. This dry air is also supplied by the RWR–AD system.

Not only the shaft seal but other points throughout the turbine called for special sealing methods. The dry air circuit also supplies a slight positive pressure to the outer compartment of the throttle valve and the governing valve lift rod steam packings, the throttle valve cover joint, the valve chest cover joint and the formed sheet metal enclosure welded around the casing horizontal joint. The vacuum system is also connected to the middle compartment of the throttle valve and governing lift rod stem packings, the leak-off grooves in the horizontal joint, the governing and throttle valve cover joints and the welded enclosure surrounding the gland steam regulator valve bodies.

The generator built for the EBWR plant is an air-cooled unit with air-to-water heat exchangers. It is rated 5MW, three-phase, 60 c/s, 3600 r.p.m., 4160V, or 6250kVA at 0·8 power factor and 0·8 short-circuit ratio. The exciter rating is 25kW, 125V d.c. A "WA-Series" generator, the unit is similar in size and rating to many of the units being built by Allis-Chalmers for industrial and municipal power stations.

Steam Condenser and Ancillary Plant

The EBWR condenser has double tube sheets and a divided water box. This enhances the precautions against the escape of radioactivity from the system and will guard against the dilution of heavy water when heavy water is used. The tubes are made of aluminium to minimise the radioactivity induced in corrosion and erosion particles. Otherwise, the condenser is of conventional design. The circulating water pumps are conventional. Two pumps circulate about 14,000 gallons per minute of cooling water to the external cooling tower.

The reactor is normally operated at constant power and steam flow rate. In order to minimise the regulation of reactor power with fluctuations in electric power demands, all excess power is removed as steam is by-passed directly to the condenser. The steam by-pass valve can be set for automatic control. With a fixed steam flow, an increase in generator load automatically causes a diversion of more steam to the turbine. If the load increase is too great the only recourse is to regulate the reactor. When the load is decreased the by-pass valve automatically directs excess steam to the condenser. The control system operates over a pressure range of 100 lb to 600 lb per square inch gauge.

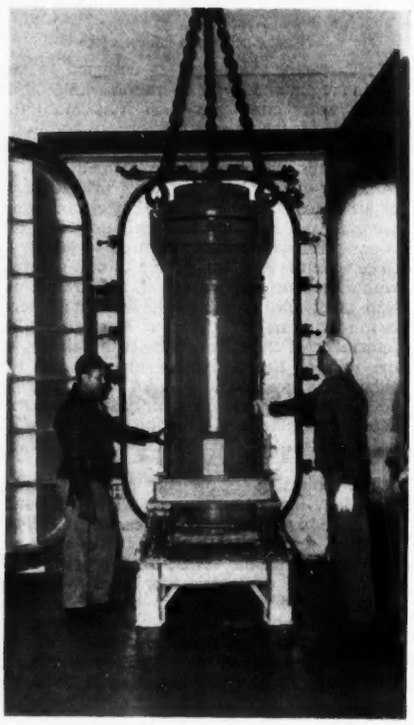
The discharge from the by-pass valve passes through a desuperheater before entering the condenser. The desuperheater, which extends across the condenser below the condenser tubes and above the water level in the divided hot well, is a 14in diameter steel pipe containing two water spray nozzles. Normally, when both halves of the condenser are operating, the spray system is not used ; the condensate water desuperheats the steam and prevents the occurrence of high temperatures in the shell and tube surfaces. However, if the condenser is operated with cooling water flowing in only half the tubes, the entry of superheated steam into the drained half could cause stresses and damage to the uncooled tubes. The automatic operation of the desuperheater spray valves will prevent such damage. In addition to automatic control, electrical control is provided for use at the discretion of the operator.

A relief valve and two safety valves discharge into the desuperheater to protect the reactor vessel in case of combined accidental closure of the turbine throttle trip valve and the by-pass valve. These valves are all integral parts of the closed steam system. The relief valve is a self-actuated, internal pilot piston-operated unit designed to pass 100,000 lb per hour at 350 lb per square inch gauge inlet. At the 640 lb per square inch gauge setting now used it will pass much more steam. The adjustable opening pressure range is 350 lb to 650 lb per square inch gauge. The two standard safety valves protect the reactor against over-pressure. One is set to open at 725 lb per square inch gauge and will discharge about 65,000 lb per hour. It will reseat at about 695 lb per square inch gauge. The second valve will open at 750 lb per square inch gauge and discharge about 65,000 lb per hour.

Before feed water enters the reactor it passes through disposable cotton filters to remove corrosion and erosion particles. For economic reasons, not all materials in the steam feed water cycle are corrosion resistant. Two parallel full-flow filters are provided ; normally one is in service and the other on stand-by duty. Each filter has a capacity of 180 gallons per minute and is capable of removing particulate matter down to 2 to 5 micron size. "Hot" filter cartridges are removed either to the cave building for cartridge replacement or, if need be, to the burial ground.

The continuous removal of corrosion products from the water in the reactor vessel is the function of the reactor purification system. This all-stainless steel system removes water from the bottom of the vessel, through one of four 6in recirculation lines and, after cooling, delivers it to the ion exchange columns. The purified water is pumped back with the feed water to the reactor vessel. The two mixed-bed ion exchange units, each 20in diameter by 84in high, have 4in of lead shielding and weigh about 18,000 lb each. Each unit contains 6 cubic feet of highly basic anion resin and 3 cubic feet of cation resin. The ion exchange beds will remove all ionic impurities and possibly some of the finer insoluble and colloidal material which passes the filters.

The air drying and fluid recovery system is designed to minimise in-leakage, to recover most out-leakage of radioactive gases and vapours, and to minimise contamination and loss of heavy water during future use of heavy water as the working fluid. The system consists



Removal of ion-exchange column from EBWR to burial ground passing through gasketed freight door of building shell

of two sections, one for drying atmospheric make-up air and the other for separating and recovering the working fluid from the sealing air. The following table lists the sealed components —

Estimated Gland Seal Flows

Item	Air required to seal, lb/hr	Air to recovery system, lb/hr	Steam to recovery system, lb/hr
H.P. turbine gland	36·4	18·2	32·7
L.P. turbine gland	36·4	18·2	32·7
Turbine lift rods (two)	1·2	1·0	2·6
Reactor feed pumps (two)	30·0	15·0	—
Pressure control valves :			
By-pass valve	0·6	0·4	0·8
Steam powered regulating valve	0·5	0·4	0·7
Throttle valve	1·6	1·0	7·0
	106·7	54·2	76·5

Chemical air driers are used to dry the make-up air and the saturated vapour and air mixture in the fluid recovery system. The unit is capable of handling 250 lb per hour of saturated air at 90 deg. Fah. for several hours. The present system is designed to hold the loss of working fluid for the entire plant down to 2 lb per day.

The start-up heat exchanger is used to preheat the reactor water to 325 deg. Fah. prior to the withdrawal of the control rods. Laboratory steam at 190 lb per square inch and 378 deg. Fah. surrounds the tubes containing the reactor water. The water within the tubes boils at atmospheric pressure until the reactor temperature reaches 212 deg. Fah. Then the tempera-

ture and pressure rise correspondingly. The flow of the reactor water is by natural circulation.

Safety Controls

Boiling water reactors have been shown, by experimental means, to possess an unusually high degree of inherent safety. If reactivity is added to a boiling reactor, by withdrawing a control rod for example, the heat generation rate increases only to a point where the reactivity subtracted by steam bubbles exactly compensates the reactivity added by the control rod. The negative reactivity effect of steam bubbles is due to the fact that the nuclear chain reaction is dependent upon having water moderator in the core. As the water boils, the steam bubbles or voids force water out from between the fuel plates.

Even though inherent safety characteristics and built-in control system render the possibility of a serious nuclear accident vanishingly small, because the EBWR is an experimental reactor, precautions have been taken against unforeseen troubles. The pressure vessel of the EBWR, with its 2½in thick steel walls, is much stronger than necessary to hold the 600 lb per square inch normal operating pressure. From an overall safety standpoint the primary concern is to prevent the escape of the radioactive fission products that are generated in the nuclear fuel elements. In the EBWR there are three levels of containment, namely the fuel elements themselves, the nuclear reactor vessel, and the pressure-tight building. The fuel elements are uranium metal plates which are clad with zirconium. They are tightly welded and tested to ensure that no radioactive materials can escape and that no water can enter to corrode the uranium itself. The steam system is completely sealed : the generator by-pass and even the relief valves, when open, pass steam to the condenser, not to the atmosphere. The power plant building itself is the third line of defence. This building is, in essence, a huge steel shell lined with concrete. In the event that any radioactive steam or gases escape from the power plant, the building will be sealed gastight by the automatic closure of the ventilation ducts which are controlled by radiation monitoring circuits. Furthermore, a water spray system is provided to quench any steam released within the building.

The structural safety provisions described above are for protection in case of a drastic accident. For steady operation and for protection against such an accident an elaborate system of automatic alarms and controls has been installed. About 100 alarm points on the annunciator panels just above the console in the control room tell the operator when an abnormal situation develops which needs attention. If this alarm goes unheeded, corrective action, usually in the form of an automatic shut-down, is taken before the situation becomes dangerous. The nine control rods at operating conditions have a combined strength greater than the amount of k (reactivity change) to be controlled. The failure of one or even two rods will not create a dangerous situation. The reactor will not be operated with less than two more than the number of rods required to control all available excess k. Any failure of the rods to reduce reactivity is backed up by a boron solution injection system. Boron is a strong neutron absorber, which, when injected into the reactor, poisons the nuclear chain reaction, causing it to stop. The system is arranged so that if the necessary number of control rods do not fully enter the core within two seconds from the time the signal is given, the prepared solution of boric acid is injected quickly under high pressure.

Since the steam cycle is a closed system, the total amount of water in the reactor and other equipment should remain constant, barring leaks. An automatic feed water regulating valve regulates the rate of introduction of condensed steam to the reactor to maintain the desired water level. The instruments that measure water level register in the control room. There are adjustable limit switches that can be set to signal an alarm or to shut down the reactor if the reactor water level should become abnormal. There are also permanent instruments in the reactor which will shut down the reactor should the water level rise or fall 2ft above or below the normal operating level. The most dangerous situations which can be imagined for the reactor are those which might cause the fuel elements to melt and allow fission products to escape from the cladding. If it could be guaranteed that the fuel elements would never melt, there would be no need for a gastight building. It is logical therefore that safety systems be designed to ensure that the fuel elements cannot melt.

Under normal steady state conditions the EBWR, operating with the present core and natural convection cooling, should be able to operate at a power level at least four times its rated level without melting even the hottest portion of the fuel. Under transient conditions in which the power level is rising rapidly the power level can go even higher before melting begins. Thus, by using automatic devices to shut the reactor down if the power level should inadvertently be allowed to exceed its rated value, the danger of melting is eliminated. Three independent " high-flux trips " which monitor the reactor heat output by measuring the neutron flux will cause the shut-down rods to be inserted automatically if the power level exceeds 20MW by more than 20 per cent. By having three such instruments, the concern over failure of one instrument to function is largely eliminated. Even when the reactor is shut down, delayed beta and gamma radiations given off by fission products represent a significant amount of heat. If all water should be lost from the core, the fuel elements would overheat and eventually melt. A great number of safety devices have been incorporated in the EBWR to prevent this from happening. For example, if a large leak should develop in the pressure vessel or its connected piping, both the pressure and the water level in the reactor would drop. Automatic devices would then turn on a water spray system within the reactor to keep the fuel elements cool. To counter the possibility that the cold water sprayed on the core could cause criticality, boric acid is added to the spray water.

The shut-down heat is normally removed by circulating a small quantity of reactor water through heat exchangers in the reactor water purification circuits. Two such circuits are provided so that if one fails the other can be used. Only in case of complete loss of electric power to the motors of the pumps would both circuits become inoperative. As a precaution against such an event, two independent sources supply incoming power to the EBWR. Even if both these sources fail, a diesel generator set starts automatically and generates enough electricity for the necessary functions when the reactor is in a shut-down condition. If this should fail also, valves open automatically to supply cooling water from the overhead water reservoir to the steam dryer emergency cooler, and shut-down heat can be removed without having electric power, or attention of any kind. All important items of equipment whose failure could lead to the shut-down of the plant are installed in duplicate. This applies to most of the pumps, for example. In some cases, such as the feed water pumps, the stoppage of one pump automatically turns on the spare unit.

Building Design

The overall arrangement of the EBWR buildings is based upon two requirements : (1) that the power plant be sealed gastight so that no steam, water, dust or gases which may contain radioactivity can escape to the atmosphere ; (2) that the entire plant be designed for operation by remote control. Accordingly, the EBWR facility is divided into two adjoining buildings—the power plant building and the operations and service building. To safeguard against contamination of the surrounding atmosphere in case of an accident which would release radioactive material within the power plant, the entire power plant building is enveloped within a welded steel shell. Economics and space considerations for a power plant of this capacity indicated that a design pressure of 15 lb per square inch gauge as a maximum for accidental pressurisation was close to the optimum. On this basis the steel shell was made concave to internal pressure throughout, with a hemi-ellipsoidal bottom head and hemi-spherical top head. Space considerations required a diameter of 80ft in the main cylindrical portion of the shell. The height of the cylindrical portion and volume of the top and bottom heads were selected to contain a maximum foreseeable pressurisation in case of a steam and gas release. The thickness of the steel plate used in the various portions of the shell conform with the requirements of the A.S.M.E. Pressure Vessel Code. All weld seams were spot tested by radiographs, particularly at weld junctures where improper fusion is most likely to occur.

Since the power plant building is constructed approximately one-half below grade, there was danger of flotation of the shell during construction in case of heavy rains. Therefore, at all times prior to the pressure and leak tests, ballast holes in the bottom head were left open. When all concrete was poured inside the building, these holes were permanently welded shut. The concrete pours and the backfilling were coordinated to minimise distortion of the shell.

Corrosion protection of the shell below grade, both inside and outside, is provided by bituminous enamel. To protect this enamel from abrasion on the outside during the backfilling operation, 1in thick commercial insulating board was applied over the enamel and left permanently in place. Above grade the shell is painted on the inside with one field coat over the shop coat and ½in thick commercial insulating board applied prior to pouring the concrete liner. Above a line 5ft below grade, the entire outside of the shell is insulated with 3in of foamglass impaled over studs which are welded to the shell. The joints between blocks are filled with mastic. A coat of mastic is applied over the foamglass and one ply of glass fibre cloth is pressed into the mastic on the cylindrical portion. On the top dome another coat of mastic and a second ply of glass cloth are applied. A final coat of mastic is then applied over the entire insulated surface and finished with two coats of aluminium paint.

The main floor is a heavy, reinforced concrete slab. The pump floor and condenser floor consist of reinforced concrete slabs in the areas where the main steam plant is situated. These slabs occupy approximately one-third of the floor area. Other areas at these levels are floored with grating supported on structural steel beams and stringers for access to various items of equipment. The grating covers approximately another one-third of the floor area. Between floors there are galleries with grating or steel checkered plate flooring for access to the reactor instrument wells, the drier and certain valves.

Permanent access means for the personnel through the building shell is provided by means of an air lock. The outer shell of the air lock is cylindrical, approximately 10ft diameter by 7ft long. The ends are closed by flat bulkheads. In each bulkhead there is a 3ft by 7ft clear opening hinged door which seals against a rubber gasket by means of a latching mechanism. The latching mechanism is geared to a valve which equalises the pressures on either side of the bulkhead before unlatching. The latching mechanisms on both doors are interlocked so that neither door can be operated unless the other is completely closed and latched. A clutch is provided in the interlocking mechanism so that the interlock may be over-ridden by operation of a lever at the outside of the outer door only. This lever is kept locked and would be used only when the reactor is shut down and it is desired that both air lock doors be open at the same time.

Permanent emergency escape and access means for the personnel are provided by an emergency air lock. Its outer shell is cylindrical and approximately 4ft diameter by 6ft long. The ends are closed by flat bulkheads, with 30in diameter round doors which seal against rubber gaskets by means of latching mechanisms. The latching mechanism is linked to a valve that equalises the pressures on either side of the bulkhead before unlatching. The latching mechanisms on both doors are interlocked so that before the valve for one door opens, the other door latches and its valve closes. The valve for the first door then opens and the door is unlatched. This air lock can also be used for emergency access to the power plant.

(To be concluded)

Personal and Business

Appointments

MR. J. J. BLISS has been appointed education officer of Marconi Instruments, Ltd.

SUNVIC CONTROLS, Ltd., has announced that Mr. J. T. Hughes has been appointed representative in Scotland.

MR. JOHN M. ARMITAGE has been appointed advertising and publicity manager of Pollard Bearings, Ltd., Ferrybridge, Knottingley, Yorks.

MR. J. ROSTRON, M.I.Loco.E., has been appointed assistant sales manager, traction department, of Metropolitan-Vickers Electrical Company, Ltd.

MR. CHARLES E. DRURY, of General Motors Corporation, has been appointed to the board of directors of the American Foundrymen's Society.

THE DUNLOP RUBBER COMPANY, Ltd., states that Mr. H. Evan Price, equipment sales manager and local director at Fort Dunlop, has been appointed local director of vehicle equipment. It has also announced the appointment of Mr. J. A. Dorr as sales manager of the manufacturers' division at Fort Dunlop; he has also been made a member of the local board of directors.

LONDON TRANSPORT, department of chief mechanical engineer (road services), has announced that, consequent upon the retirement of Mr. C. T. Goodchild, Mr. A. F. Tame has been appointed an officer of the executive with the title works superintendent (Aldenham).

Business Announcements

WICKMAN, Ltd., states that Mr. J. W. Buchanan has relinquished his appointment on reaching retiring age.

THE NORTON GRINDING WHEEL COMPANY, Ltd., states that Mr. J. C. Ewer will shortly be leaving to take up a new appointment in the Norton Company, U.S.A.

REMINGTON RAND, Ltd., has announced the formation of a photo records division and the appointment of Mr. J. O. V. Christian as its national sales manager.

THE BRITISH TRANSPORT COMMISSION states that a party of twelve senior officers of British Railways and British Road Services are to make a four-weeks' study tour in America.

ACHESON COLLOIDS, Ltd., announces that its technical sales and service department is now situated at 70, Hill Street, Richmond, Surrey (telephone, Richmond 2066 and 2634).

CLARKE, CHAPMAN AND CO., Ltd., states that it has opened a branch office at 8, King Street, Manchester, 2 (telephone, Deansgate 4204). Mr. J. O. Chaloner has been appointed manager.

THE BUTTERLEY COMPANY, Ltd., and Air Products Incorporated of America have announced the formation of a company, to be known as British Air Products, Ltd., for the manufacture of extreme low temperature equipment and the production of industrial gases in the United Kingdom, British Commonwealth of Nations and Europe.

KEITH BLACKMAN, Ltd., states that it has concluded an agreement with Prat-Daniel (Stanmore), Ltd., by which both companies will be able to offer complete draught equipment for power station and industrial work. An agreement has also been made with the Aerotec Corporation of America, resulting in the introduction of electrostatic precipitators to the range of both companies.

Contracts

THE BRITISH TRANSPORT WATERWAYS announces that a contract has been placed with Leonard Fairclough, Ltd., Adlington, Lancs, for the construction of a towing path wall, in mass concrete, over a length of 1500ft on the Limehouse Cut, which links the Lee with the Thames.

Miscellanea

GIANT EARTHMOVER TYRES.—Tyres for giant earthmoving vehicles of American origin are now being produced by the Dunlop Rubber Company at Birmingham. The tyres, which weigh a ton with tube and flap, are 7ft 5in diameter and 2ft 5in wide across the tread ; at 30 m.p.h. the carrying capacity is as follows :—24-ply rating, 29,890 lb at 40 lb per square inch; 30-ply rating, 34,060 lb at 50 lb per square inch; 36-ply rating, 37,890 lb at 60 lb per square inch. The standard tyre rubber compound is used, but the cord is nylon. These are the largest tyres ever made in this country, the mould weighing 18 tons; production is sufficient to meet the demands of the thirty vehicles in Great Britain using such tyres and allow substantial exports.

DECTRA PROGRESS.—We are informed by the Decca Navigator Company, Ltd., that, as part of the Dectra plan for the North Atlantic, the masts of the master station at Comfort Cove, on the north coast of Newfoundland, and the slave station at Thorburn Lake, south of Port Blandford, have been erected and the stations are on the air. It is expected that the English stations, the master station near Stirling and the slave station near Whithorn, Wigtonshire, will be transmitting shortly.

BRITISH TRANSPORT COMMISSION PUBLICATION.—A new quarterly publication, *Transport Age*, has been introduced by the British Transport Commission with a view to providing a link between the British Transport system and the industries it serves. The journal is being distributed to all the principal trading and manufacturing customers of the nationalised transport services. It will deal mainly with freight services offering the combined facilities of rail, road and water transport.

NORTH EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.—On April 12, J. H. Milton presented his paper, " Marine Machinery Break-Downs," before the North East Coast Institution of Engineers and Shipbuilders. The paper is of a practical nature and describes many failures that have occurred in service in marine steam reciprocating engines, turbines, auxiliaries, boilers, and diesel propelling machinery. Details are given of a number of temporary and permanent repairs and there are a large number of illustrations.

PORTABLE WATER PURIFYING PLANT.—The Permutit Company, Ltd., has introduced the Mark V Portable " Deminrolit " Plant, which is capable of supplying six gallons per hour of distilled quality water without use of heat or power. The unit consists of two columns of ion exchange material. In the first is Permutit " Zeo-Karb" cation exchange material, where the mineral salts in the raw water are converted to their corresponding acids. The second column contains Permutit " De-Acidite " ion exchange material which absorbs the acids.

APAPA WHARF, LAGOS.—A new colour film entitled " Cutting the Queue," produced by the film unit of Richard Costain, Ltd., was shown before an invited audience in London last week. The film tells the story of the building of a half-mile extension to the existing Apapa Wharf at Lagos, the principal seaport of the Federation of Nigeria. The pumping of some 2,500,000 tons of sand from the lagoon is followed by the laying of a bed to receive the concrete blocks, each weighing between 8 and 15 tons, which form the wharf wall. More than 11,000 of these concrete blocks were cast locally and placed in the wall. Storage and transit facilities now cover the 100 acres of land reclaimed. This film is available in 16mm size.

ASSAY FURNACE.—A new assay furnace made by Royce Electric Furnaces, Ltd., of Sir Richard's Bridge, Walton-on-Thames, Surrey, is stated to be suitable for use in the mining and metallurgical industries as well as in applications where a self-contained source of high-temperature treatment is required, such as in the electrical and electronic industries, and in tool treatment. The furnaces are specially designed for fusing and cupellation. They have silicon carbide rod resistor elements suitable for service temperatures of up to 1350 deg. Cent., which ensure a long operational life for assaying gold at 1050 deg. Cent. or copper at 1150 deg. Cent.

AIR DRIERS.—We are informed by The Lightfoot Refrigeration Company, Ltd., Abbeydale Road, Wembley, Middlesex, that the company has developed an air dryer which will maintain high operating efficiency at temperatures down to below freezing point. A simple auto-defrosting device, arranged for either automatic or hand control, is fitted. The machine, which is housed in an enamelled casing, is fitted with a $\frac{1}{4}$ h.p. hermetically sealed refrigerating system and is capable of removing thirty pints of water per day, depending upon relative humidity. Overall dimensions are 1ft $1\frac{1}{4}$in by 1ft 10in by 1ft 4in high, and the units are available for electrical supply of 220V to 240V at 50 c/s or 110V to 120V at 60 c/s.

CAMBERED SUPERSONIC WINGS.—The January, 1957, issue of the *Journal of the Aeronautical Sciences* includes a note by Doris Cohen on the subject of the warping of wings of triangular plan form for minimum drag at supersonic speeds. The shapes derived have generally negative camber when the wing lies entirely within the Mach cone of the apex, except for a reversal of the curvature in the vicinity of the rear third of the root section. As the leading edge approaches the Mach cone, the region of positive camber spreads spanwise and then forward, so that for a half-angle of 50 deg. in a Mach $\sqrt{2}$ stream, the indicated camber is for the most part positive. Wash-out is consistently indicated, particularly for the wider wings.

THE PRODUCTION OF STEEL.—A new colour film entitled " Steel Rhythm," produced by Wallace Productions, Ltd., for the Steel Peech and Tozer branch of the United Steel Companies, Ltd., was shown in London last week. The film reviews the works, the 7000 craftsmen, engineers and scientists employed there and the general amenities. Charging, refining, tapping, teeming, and stripping are shown in great detail in the melting shop, where much emphasis is placed on quality control. This sequence is followed by the reheating of the ingots in the soaking pits prior to their delivery to the cogging mill, where further processes are illustrated. The forging of a 60-ton ingot is demonstrated, and a short section deals with heat-treatment. The film is available in 16mm and 35mm sizes.

INSTITUTE OF MARINE ENGINEERS.—At a joint meeting of the Institute of Marine Engineers and the Institution of Naval Architects, held on April 9, R. Atkinson, B.Sc. (Eng.), read a paper entitled " Design and Operating Experience of an Ore Carrier Built Abroad." A carrier transporting bauxite and alumina is loaded to its deadweight capacity on every voyage to the smelter, but with considerable cubic capacity to spare. Return voyages have to be in ballast or carrying general cargo, while it is possible that the trade may be seasonal. The paper discusses design considerations such as the general arrangement, position of machinery and ballasting arrangements, and gives particulars of the ship, including the economic analysis resulting in the adoption of aluminium alloy for the superstructure and certain fittings to increase deadweight capacity. Constructional details are recorded ; also factors influencing the choice between a.c. and d.c. systems, together with a description of the main propelling machinery.

IMPROVEMENTS AT IMMINGHAM AND BARROW DOCKS.—British Transport Docks is to spend £600,000 on the modernisation of the quay cranage and ancillary work at Immingham Dock and over £250,000 on improving import facilities for iron ore traffic at Barrow Docks. At Immingham eleven electric cranes with lifting capacities of up to 6 tons are to be installed at the general cargo quays, where transit sheds are available ; at the mineral quay, four new 10-ton grab cranes and two 6-ton cranes will, together with four 10-ton cranes recently provided, complete the renewal programme there. All seventeen new appliances will operate on a track of 15ft gauge and will have a maximum jib radius of 65ft. They will replace hydraulic cranes of smaller lifting capacity and radius. The layout of the quays will also be modernised by the strengthening of the supports, repaving of the surfaces in concrete and renewal of crane and railway tracks. At Barrow, to cater for the increasing quantity of iron ore imported through the docks, a scheme has been approved for the reconstruction and modernisation of 340ft of quay. Two 10-ton electric grab cranes and three railway lines will be provided, and the scheme, when completed, will make available a continuous quay 880ft in length equipped with seven 10-ton grab cranes.

SHIP VIBRATION—On April 1, A. J. Johnson, Ph.D., and P. W. Ayling, B.Sc., read a paper, " Graphical Presentation of Hull Frequency Data and the Influence of Deck-Houses on Frequency Prediction," before the North East Coast Institution of Engineers and Shipbuilders. The paper is concerned with the presentation of ship-vibration data in a form aimed at enabling quick estimates of frequencies to be made at the design stage. The subject matter represents one aspect of a comprehensive programme of work on ship vibration being carried out by the British Shipbuilding Research Association. Previously published methods have been adapted for this purpose but experimental results have enabled these methods to be extended and modified with the intention of improving the accuracy of the estimates. Detailed consideration is given to the flexural rigidity of ships having deckhouses. On the basis of a specific method for estimating the distribution of longitudinal stress in deckhouses, a series of calculations was carried out for a wide range of ships and graphs derived from which inertia correction factors can be obtained. Particulars are given of five basic ships, together with graphs of correction factors shown as a function of ship length and deckhouse length for single and double-tier houses. Data is given for seven ships and plots of two mode horizontal frequencies, together with a graph of an approximation to higher vertical mode frequencies.

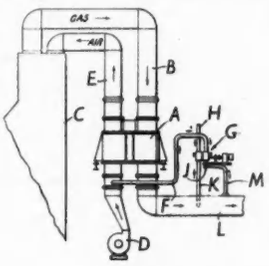
British Patent Specifications

When an invention is communicated from abroad the name and address of the communicator are printed in italics. When an abridgment is not illustrated the specification is without drawings. The date first given is the date of application; the second date, at the end of the abridgment, is the date of publication of the complete specification. Copies of specifications may be obtained at the Patent Office Sales Branch, 15, Southampton Buildings, Chancery Lane, W.C.2, 3s. 6d. each.

STEAM GENERATORS

770,242. April 5, 1955.—HEAT EXCHANGERS, Svenska Rotor Maskiner Aktiebolag, Nacka, Sweden.

The invention relates to heat exchange apparatus wherein hot and cold gases exchange heat in out-of-contact relation. A primary object of the invention is to provide an indicator system which permits continuous observation of conditions within an operating heat exchanger. The arrangement shown in the drawing comprises a primary air preheater *A* having a gas inlet port connected to the flue gas outlet *B* of a boiler *C*. Air for combustion in the boiler is supplied by the forced draught fan *D* to the air side of the preheater where it absorbs heat from the gas passing there-through before it passes on through



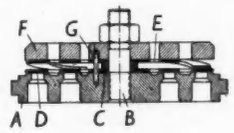
No. 770,242

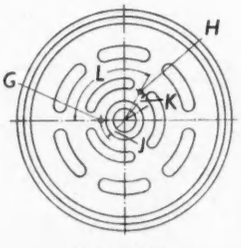
duct *E* to the boiler. Before the combustion air reaches the preheater *A*, a small portion is tapped off through a duct *F* to the air side of the heating surface condition indicator *G* where it is placed in heat transfer relationship with a portion of the gas from the gas outlet side of preheater *A* and is then vented to the atmosphere through duct *H*. The hot gas from the preheater *A* is drawn to the indicator *G* by an ejector *J*. Hot gas enters the duct *K* and after traversing the indicator is returned to the main gas exhaust duct *L* through duct *M*. As the hot gases and air for combustion meet in heat transfer relationship within the indicator *G* at substantially the same or lower temperatures than encountered in the primary heat exchanger, it is apparent that there will be a near duplication of condensation, corrosion and dust deposit conditions. Therefore, by making the effects of these conditions visible through observation windows in the indicator housing, an indication of comparative conditions within the primary heat exchanger may be obtained. Modified designs for a regenerative type of heat exchanger with further details of the surface condition indicator are also included in the specification.—*March* 20, 1957.

VALVES

770,825. June 14, 1955.—ANNULAR PLATE CHECK VALVES, Martina Hoerbiger, Sole Partner of Hoerbiger and Co., 23, Braunhubergasse, Vienna XI, Austria.

The subject of the invention is a check valve in which two guiding pins are provided. It will be seen



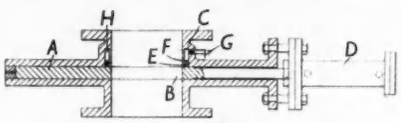


No. 770,825

from the drawing that *A* is the valve seat, *B* the central assembly screw, *C* the guide ring for the valve plate *D* and the spring plate *E*. The spring plate lies against the guard plate *F* and is supported on blades from the valve plate. Guiding pins *G* and *H* are located at distances *J* and *K* from the valve axis at an angle *L*, which is less than 180 deg. The pins are a press-fit in the valve seat and project freely into a bore in the guard plate. A similar arrangement of such locating pins is also suitable for other forms of valve construction, such as those with link guided valve plates, damping and spring plates.—*March* 27, 1957.

770,775. July 26, 1954.—VALVES FOR USE IN BORING RIGS, Niels Matheson, Jackdaws, Burghfield Common, near Reading, Berkshire.

The invention relates to gate valves and more particularly, though not solely, to valves for use in boring rigs. In what is known as reverse circulation drilling it very often happens that it is necessary to operate quickly a number of valves, most of which are operating under vacuum and great difficulty is experienced in doing this while ensuring that the valves are



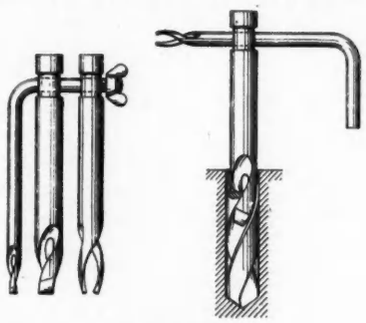
No. 770,775

adequately sealed. The object of the invention is to overcome this difficulty in sealing. In the drawing the valve is applied to the control of flow through a drill pipe, a plate valve *A* having a hole *B*, the area of which corresponds to the area of the bore of the drill pipe, and a blank portion of sufficient area to close the drill pipe. The plate is slidable in a flanged body *C* and is operated by a piston or hydraulic cylinder *D*, or it may be operated by hand or electrically. The plate may be slidable against a flexible steel ring *E* to which is bonded a U-section rubber ring *F*, which may be subjected to pressure applied through a pipe *G* to an annular cavity *H*. Alternatively, the plate valve may be slidable between two flexible rings. The sealing pressure applied behind the rings may be fluid pressure applied by means of an auxiliary piston so arranged and controlled that each time the valve is opened or closed sufficient pressure is built up by the auxiliary piston to make an effective seal. An alternative method of applying the pressure to the seal could be by means of a grease gun automatically operated with the opening and closing of the valve.—*March* 27, 1957.

WORKSHOP TOOLS AND APPLIANCES

770,849. June 21, 1955.—EXTRACTORS FOR REMOVING BROKEN DRILL PIECES FROM HOLES, Otto Schumacher, Hubert Schumacher and Paul Fluegel, trading as the firm Aggertaler Spiralbohrer-Und Werkzeugfabrik Gemerski and Co., of Engelskirchen-Hardt, Rheinland, Germany.

The invention concerns a tool, for removing a piece of a drill which has been broken off and become stuck in a hole, which is very effective, easy to manufacture



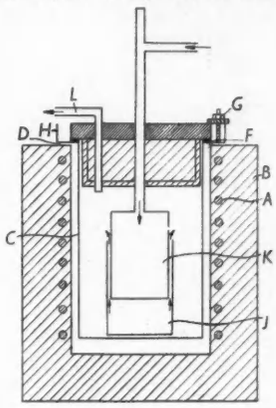
No. 770,849

and inexpensive. The general construction of the extractors is clearly shown in the drawing. A group of three extractors forming a set is shown to the left, and on the right the process of extraction is illustrated, one of the smaller diameter extractors being utilised as a wrench passed through a bore in the head of the larger diameter extractor. The form of the two prongs shown at the end of the extractors may be tapered by grinding.—*March* 27, 1957.—

METALLURGY

771,351. January 21, 1953.—BRIGHT ANNEALING OF BRASS, The General Electric Company, Ltd., Magnet House, Kingsway, London, W.C.2. (*Inventors: Douglas Marshall Dovey and Peter Graham Simpson.*)

The invention relates to the bright annealing of brass in batches, and to furnaces in which the bright annealing may be carried out. The drawing shows a vertical section through the centre of a furnace heated electrically by means of a coil *A* embedded in the refractory furnace wall *B*. A cylindrical outer pot *C* of a heat-resistant, nickel-chromium alloy is suspended within the furnace chamber by a flange *D*, which rests upon the top of the furnace wall; the top of the wall has an irregular surface to allow air to pass freely into and out of the space between the wall and the pot. The pot cover, of refractory



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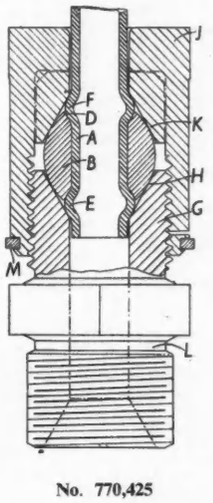
material in a casing of nickel-chromium alloy, is sealed to the flange *D* by a rubber ring *F* and a number of clamps *G*. The flange *D* is provided with a vertical wall *H* to form a channel around which water flows for cooling the rubber ring seal. Enclosed within the outer pot *C* there is a mild steel cylindrical container consisting of a lower part *J* resting on the bottom of the outer pot *C*, and an upper part *K* which is a sliding fit within the lower part and is provided with a pipe passing through the cover to serve as the inlet for reducing gases. An outlet for the gases is provided by a pipe *L*. The directions of gas flows are indicated in the drawing by arrows. In one particular furnace of the form shown in the drawing the inner container is 6in in diameter and 11in high, and the outer pot is 8in in diameter and 14in high.—*April* 3, 1957.

PIPE AND TUBE COUPLINGS

770,425. May 5, 1954.—PIPE COUPLINGS, Thos. P. Headland, Ltd., 164/168, Westminster Bridge Road, London, S.E.1. (*Inventor: Sidney Walter Prosser.*)

The invention relates to pipe couplings which are capable of withstanding very high pressures. In the drawing the pipe is shown at *A* and the seating member, in the form of a hardened steel ball, at *B*. The ball is bored and at the end of the bores is provided with tapering flutes *D*. When the ball is located the pipe is outwardly bulged at *E* and *F* by longitudinally compressing the pipe and the ball becomes securely positioned on the pipe. The particular advantage of effecting the bulging operation by longitudinal compression of the pipe is that it safeguards the material of the pipe against work hardening. A suitable tool for performing this function is described in Specification No. 770,424. The union nut *G* has a seating *H* to co-operate with the surface of the ball. The locking nut *J* co-operates with the union nut *G* to make the coupling and between the nut and the adjacent surface of the ball there is a thimble or washer *K* which seats on the ball. Alternatively the thimble or washer may form part of the nut. The size of the bulges on each side of the ball is important, the radius of the bulges being just sufficient for the fluted portions *D* of the ball to nip the bulge on tightening up the joint. The union nut *G* is located on a screwed portion of a vessel or another pipe schematically shown at *L*. In order to retain the locking nut *J* when the joint is made, a circlip *M* may be provided for clamping the nut into the threads of the union *G*.—*March* 20, 1957.



No. 770,425

Launches and Trial Trips

BRITISH RENOWN, oil tanker ; built by Joseph L. Thompson and Sons, Ltd., for the B.P. Tanker Company, Ltd.; length between perpendiculars 515ft, breadth moulded 69ft 6in, depth moulded 37ft 6in, deadweight 16,000 tons on 30ft summer draught ; service speed 13¾ knots ; twenty-seven oil cargo compartments, two cargo pump rooms ; Hawthorn-Doxford oil engine, six cylinders, 670mm diameter by 2320mm combined stroke, 6800 b.h.p. at 119 r.p.m. Launch, January 31.

FOULAYA, banana-carrier ; built by the Chantiers Réunis Loire-Normandie for the Compagnie de Navigation Fruitière ; length between perpendiculars 344ft 6in, breadth moulded 50ft 6½in, depth to shelter deck 34ft 5½in, capacity 184,000 cubic feet ; speed 16 knots ; Burmeister and Wain diesel engine mark 762VTBF125.—Trial, January.

SAMARRAH, oil tanker ; built by the Chantiers de l'Atlantique (Penhoët-Loire) for the Compagnie Navale des Petroles ; length overall 651ft 3in, length between perpendiculars 607ft, breadth moulded 83ft 8in, depth 43ft 8in, draught loaded 33ft, deadweight 29,600 tons, service speed 15 knots ; twenty cargo oil tanks ; Burmeister and Wain diesel engine mark 974VTF/160 of 11,250 h.p.—Trial, January.

GEORGE F. GETLY, oil tanker ; built by the Chantiers de l'Atlantique (Penhoët-Loire) for the Tide Water Oil Company ; length overall 782ft, length between perpendiculars 747ft 11in, breadth moulded 102ft ½in, depth 51ft 8in, draught maximum 38ft 6in, deadweight 51,850 tons, load displacement 67,100 tons ; service speed 16½ knots ; thirty-six cargo oil compartments ; one set of C.E.M. Parsons geared turbines of 17,480/19,000 s.h.p. taking steam at 600 lb per square inch and 850 deg. Fah.—Trial, January.

Catalogues and Brochures

SOAG MACHINE TOOLS, Ltd., Juxon Street, Lambeth, London, S.E.11.—Leaflets containing details of second-hand and rebuilt heavy duty lathes, milling machines and metal sawing machines which are available from stock.

THE YALE AND TOWNE MANUFACTURING COMPANY, Wednesfield, Wolverhampton.—Illustrated folder giving details of all-welded steel gooseneck booms for use with "Yale" Series 51 and "Worksaver" electric fork lift trucks.

DEWRANCE AND CO., Ltd., Great Dover Street, London, S.E.1. —Illustrated folder giving particulars of "Endewrance" hard facing welding rods. A table showing the physical properties of these rods and some typical uses is included.

STANDARD TELEPHONES AND CABLES, Ltd., Transmission Division, North Woolwich, London, E.16.—Illustrated folder giving technical details of voltage regulators for a.c. mains, 2kVA and 4kVA. A layout diagram is included.

ASHWORTH AND PARKER, Ltd., Riverside Works, Bury, Lancs. —Illustrated booklet describing "Rotoklene" self-cleaning strainers. The design and working of these strainers is explained and a table at the end gives dimensions and weights.

COVENTRY GAUGE AND TOOL COMPANY, Ltd., P.O. Box 39, Fletchamstead Highway, Coventry.—Leaflet describing a unit intended to demonstrate the clearance obtained in recommended fits between shafts and holes of mating cylindrical parts.

Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office not later than a fortnight before the meeting. In all cases the TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

ASSOCIATION OF SUPERVISING ELECTRICAL ENGINEERS

Sat., April 27.—OXFORD, READING AND DISTRICTS BRANCH : Collier Lecture Room, Regents Park College, Pusey Street, Oxford, "Applications of the Cathode-Ray Tube," C. H. Gardner, 6.30 p.m.

Wed., May 1.—GLASGOW BRANCH : Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, Annual General meeting, 7.30 p.m. ★ MANCHESTER BRANCH : Engineers' Club, Albert Square, Manchester, "Management in Industry," 7.30 p.m. ★ PRESTON BRANCH : R.A.F.A. Club, East View, Preston, "Emergency Lighting Equipment," A. S. Wolstenholme, 7.30 p.m.

Fri., May 3.—LIVERPOOL BRANCH : Liverpool Engineering Society, 9, The Temple, 24, Dale Street, Liverpool, "Electrical Installation in Modern Cargo Vessel," A. Robertson, 7.30 p.m.

BRITISH INSTITUTION OF RADIO ENGINEERS

To-day, April 26.—SCOTTISH SECTION : Department of Natural Philosophy, University of Edinburgh, Annual General Meeting, followed by "Special Process Instrumentation in Atomic Energy Projects," H. Bisby, 6.30 p.m.

BRITISH INTERPLANETARY SOCIETY

Sat., May 4.—Science Museum Lecture Theatre, Exhibition Road, London, S.W.7, Film Shows, 2.30 p.m. and 6.30 p.m.

COMBUSTION ENGINEERING ASSOCIATION

Wed., May 1.—N.W. SECTION : Engineers' Club, Albert Square, Manchester, "Comparison of Conventional Space Heating Systems," J. R. Kell, 10.30 a.m.

ENGINEERS' GUILD

Mon., April 29.—EDINBURGH CENTRE : Scottish Liberal Club, Prince's Street, Edinburgh, Annual General Meeting, 6.15 p.m. ★ S.W. ESSEX CENTRE : Dr. Johnson Hotel, Barkingside, "Rural Preservation," J. A. Fisher, 8 p.m.

ILLUMINATING ENGINEERING SOCIETY

To-day, April 26.—BATH AND BRISTOL CENTRE : S.W. Electricity Board, Bath, Annual General Meeting, 7 p.m. ★ BIRMINGHAM CENTRE : Regent House, St. Phillip's Place, Colmore Row, Birmingham, "A Feminine View Point on Domestic Lighting," Mrs Kay Hudson, 6 p.m.

Thurs., May 2.—NOTTINGHAM CENTRE : Electricity Service Centre, Smithy Row, Nottingham, Annual General Meeting, 5.30 p.m.

INCORPORATED PLANT ENGINEERS

To-day, April 26.—BIRMINGHAM BRANCH : Imperial Hotel, Temple Street, Birmingham, "Earthing and Earth Leakage Protection," J. A. Robbins, 7.30 p.m.

Mon., April 29.—WEST AND EAST YORKSHIRE BRANCH : Leeds University, Films, "Basic Principles of Lubrication," and "Let go Fee'ard," 7.30 p.m. ★ Cromwell Hall, Earls Court Exhibition Building, London, S.W.5, "An Engineer Looks Ahead—Modern Trends in Factory Design and Equipment," E. C. Stevens, 2 p.m.

Wed., May 1.—SOUTHERN BRANCH : Polygon Hotel, Southampton, "Liquid Petroleum Gases," C. F. Port, 7.30 p.m.

Tues., May 7.—LONDON BRANCH : Royal Society of Arts, John Adam Street, Adelphi, Strand, London, W.C.2, "Contemporary Plant Engineering in the U.S.A.," H. M. Sylvester, 7 p.m.

INSTITUTE OF FUEL

Wed., May 1.—LONDON BRANCH : Institution of Civil Engineers, Great George Street, Westminster, London, S.W.1, "Fuel Uses and Fuel Economy in Italy," Carco Padovani, 5.30 p.m.

INSTITUTE OF MARINE ENGINEERS

Mon., April 29.—W. OF ENGLAND SECTION : Grand Hotel, Bristol, Films, "The Back of Beyond," "Rig 20," and "We've Come a Long Way," 7.30 p.m.

Tues., April 30.—85, Minories, London, E.C.3, Annual General Meeting, 5.30 p.m.

INSTITUTE OF METALS

Mon. to Fri., April 29 *to May* 3.—JOINT SPRING MEETING : Monday to Wednesday, Church House, Great Smith Street, Westminster, London, S.W.1 ; Thursday, 17, Belgrave Square, Westminster, London, S.W.1, followed by visits.

Mon., April 29.—GENERAL MEETING : Royal Institution, Albemarle Street, Piccadilly, London, W.1, Annual May Lecture, 6.30 p.m.

Tues., April 30.—GENERAL MEETING : Church House, Great Smith Street, Westminster, London, S.W.1, Annual General Meeting and Presidential Address, L. B. Pfeil, 9.30 a.m.

INSTITUTE OF METALS AND INSTITUTE OF BRITISH FOUNDRYMEN

Wed., May 1.—Church House, Great Smith Street, Westminster, London, S.W.1, Symposium on "Metallurgical Aspects of the Control of Quality in Non-Ferrous Castings," 9.30 a.m.

INSTITUTE OF NAVIGATION

To-day, April 26.—Royal Geographical Society, 1, Kensington Gore, London, S.W.7, "Methods of Obtaining a Ship's Aspect and Speed by Radar," R. G. Swallow and A. L. P. Milwright, 5.15 p.m.

INSTITUTE OF PETROLEUM

Wed., May 1.—LONDON BRANCH : 26, Portland Place, London, W.1, "The Properties and Use of Bitumen in Road Making," A. R. Lee, J. H. Nicholas and P. C. Leaver, 5.30 p.m.

INSTITUTE OF PHYSICS

To-day, April 26.—S. WALES BRANCH : University College of Wales, Aberystwyth, "Instrumentation of the Liverpool Synchrocyclotron," B. Collings, 5.30 p.m.

INSTITUTE OF REFRIGERATION

Thurs., May 2.—LONDON MEETING : Junior Institution of Engineers, Pepys House, 14, Rochester Row, Westminster, London, S.W.1, "The Detection of Refrigerant Leaks," A. C. Murdoch, 5.30 p.m.

INSTITUTE OF ROAD TRANSPORT ENGINEERS

Tues., April 39.—E. MIDLANDS CENTRE : Mechanics' Institute, Nottingham, Annual General Meeting, 7.30 p.m.

Thurs., May 2.—W. REGIONAL CENTRE : Adelphi Hotel, Lime Street, Liverpool, Annual General Meeting, 7.30 p.m.

INSTITUTION OF CHEMICAL ENGINEERS

To-day, April 26.—GRADUATES AND STUDENTS' SECTION : Cora Hotel, Upper Woburn Place, London, W.C.1, a Symposium on "The Impact of Atomic Energy on Chemical Engineering," 9.45 a.m.

Sat., April 27.—GRADUATES AND STUDENTS' SECTION : 16, Belgrave Square, London, S.W.1, Annual General Meeting, 10.30 a.m.

Tues., April 30.—May Fair Hotel, Berkeley Street, London, W.1, Thirty-fifth Annual Corporate Meeting, 11 a.m.; Annual Dinner, 7 p.m.

INSTITUTION OF CIVIL ENGINEERS

To-day, April 26.—Grand Hotel, Sheffield, Annual General Meeting, "Skidding Resistance of Roads and the Requirements of Modern Traffic," C. G. Giles, 6.15 p.m.

Thurs., May 2.—Dorchester Hotel, Park Lane, Piccadilly, London, W.1, Annual Dinner, 7 p.m. ★ N.W. ASSOCIATION : Engineers' Club, 17, Albert Square, Manchester, Annual General Meeting, 6.30 p.m.

Fri., May 3.—SOUTHERN ASSOCIATION : Assembly Rooms, North Street, Chichester, Annual General Meeting, followed by Films, "Boring at Sea," and "Power for Uganda," 6 p.m.

Tues., May 7.—PUBLIC HEALTH (B) MEETING : Great George Street, Westminster, London, S.W.1, "Water Supply for Doha, Qatar," Charles Hogg and G. M. Swan, 5.30 p.m.

INSTITUTION OF ELECTRICAL ENGINEERS

Mon., April 29.—RADIO AND TELECOMMUNICATION SECTION : Savoy Place, London, W.C.2, Informal Evening on "Radio in Air-Sea Rescue," G. W. Hosie, D. Kerr and W. Kiryluk, 5.30 p.m. ★ S. MIDLAND RADIO AND TELECOMMUNICATION GROUP : James Watt Memorial Institute, Great Charles Street, Birmingham, Annual General Meeting, 6 p.m.

Tues., April 30.—S.E. SCOTLAND SUB-CENTRE : Carlton Hotel, North Bridge, Edinburgh, Annual General Meeting, followed by "Applications of Magnetic Amplifiers," C. Cowan, and "Stereophonic Sound," G. I. Thomas, 7 p.m.

Wed., May 1.—S.W. SCOTLAND SUB-CENTRE : Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, Annual General Meeting, followed by "The Early Development of Radar," Miss S. McL. Weir, 7 p.m. ★ N. LANCASHIRE SUB-CENTRE : N.W. Electricity Board, 19, Friargate, Preston, Informal Lecture on "The Television Studio as Seen by the Producer," Alvin Rakoff, 7.15 p.m.

Mon., May 6.—EDUCATION DISCUSSION CIRCLE : Savoy Place, London, W.C.2, Discussion on "The Co-ordination of Education and Practical Training in Sandwich Courses," opened by C. Grad and A. Draper, 6 p.m. ★ S. MIDLAND CENTRE : James Watt Memorial Institute, Great Charles Street, Birmingham, Discussion on "The Influence of Maintenance Requirements on the Design of Industrial Electrical Equipment," opened by H. C. Fox and J. H. Harris, 6 p.m. ★ N. STAFFORDSHIRE SUB-CENTRE : North Stafford Hotel, Stoke-on-Trent, Annual General Meeting, "Electricity in Modern Commercial Horticulture," C. A. Cameron Brown and A. W. Gray, 7 p.m.

Tues., May 7.—MEASUREMENT AND CONTROL SECTION : Savoy Place, London, W.C.2, "Invention and Nature," F. W. Meredith, 5.30 p.m. ★ N. MIDLAND CENTRE : Central Electricity Authority, 1, Whitehall Road, Leeds, Annual General Meeting, 6.30 p.m. ★ N.W. CENTRE : Engineers' Club, 17, Albert Square, Manchester, Annual General Meeting, "Lighting for the Amateur Stage," F. Day, 6.15 p.m.

INSTITUTION OF HEATING AND VENTILATING ENGINEERS

Tues., April 30.—SCOTTISH BRANCH : Scottish Building Centre, 425, Sauchiehall Street, Glasgow, Annual General Meeting, followed by "Air Conditioning in the British Isles," J. C. Knight, 7 p.m. ★ LONDON ASSOCIATE MEMBERS, GRADUATES AND STUDENTS' BRANCH : Junior Institution of Engineers, Pepys House, 14, Rochester Row, London, S.W.1, Annual General Meeting, 6.30 p.m.

INSTITUTION OF MECHANICAL ENGINEERS

To-day, April 26.—1, Birdcage Walk, Westminster, London, S.W.1, Annual General Meeting and Annual Report, 6 p.m.

Mon., April 29.—N.E. BRANCH : Neville Hall, Westgate Road, Newcastle upon Tyne, "Some Engineering Problems in the Industrial Development of Nuclear Power," Sir Claude Gibb, 6 p.m.

Tues. to Thurs., April 30 *to May* 2.—1, Birdcage Walk, Westminster, London, S.W.1, Conference on "Properties of Materials at High Rates of Strain."

Thurs., May 2.—SCOTTISH BRANCH : Visit to G. and J. Weir, Ltd., Cathcart, 7.30 p.m.

Fri., May 3.—GENERAL MEETING IN CONJUNCTION WITH THE APPLIED MECHANICS GROUP : 1, Birdcage Walk, Westminster, London, S.W.1, "Influence of Dynamical Imperfection on the Vibration of Rotating Discs," S. A. Tobias and R. N. Arnold, and "Free Undamped Non-Linear Vibrations of Imperfect Circular Discs," S. A. Tobias, 6 p.m.

Thurs., May 9.—SCOTTISH BRANCH : Visit to G. and J. Weir, Ltd., Cathcart, 7.30 p.m. ★ E. MIDLANDS GRADUATES' SECTION : Art Gallery (Strand Entrance), Derby, Annual Meeting, 7.15 p.m.

INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS

Mon., May 6.—ORDINARY MEETING : Institution of Electrical Engineers, Savoy Place, London, W.C.2, "The Rugby 'B' H.F. Radio Transmitting Station," A. Cook and L. L. Hall, 5 p.m.

INSTITUTION OF PRODUCTION ENGINEERS

Mon., April 29.—N.W. REGION : Great Hall, College of Science and Technology, Manchester, "Human Relations in Industry," J. H. Brebner, 6.30 p.m.

Tues., April 30.—LONDON GRADUATE SECTION : 10, Chesterfield Street, London, W.1, "The Development and Application of Hard Metals," R. N. Cooke, 7.15 p.m.

Wed., May 1.—NOTTINGHAM SECTION : Visit to Vauxhall Motors, Ltd., Luton, 10.30 a.m.

INSTITUTION OF THE RUBBER INDUSTRY

To-day, April 26.—MERSEYSIDE SECTION : Stork Hotel, Liverpool, Annual General Meeting, 6.15 p.m.

INSTITUTION OF STRUCTURAL ENGINEERS

Tues., April 30.—WALES AND MONMOUTHSHIRE BRANCH : S. Wales Institute of Engineers, Cardiff, "Wind Stresses on Buildings," H. Ferrington, 6.30 p.m.

JUNIOR INSTITUTION OF ENGINEERS

Mon., April 29.—SHEFFIELD AND DISTRICT SECTION : Royal Victoria Hotel, Sheffield, Presidential Address, "Fuel Economy and Heat-Electric Generation," Bryan Donkin, 7.30 p.m.

Tues., April 30.—N.W. SECTION : Engineers' Club, Albert Square, Manchester, Presidential Address, "Fuel Economy and Heat-Electric Generation," Bryan Donkin, 7.30 p.m.

Wed., May 1.—MIDLAND SECTION : James Watt Memorial Institute, Great Charles Street, Birmingham, Film Evening and Joint Meeting with the Festiniog Railway Society, Ltd., "F.R. Progress Report," 7 p.m.

PLASTICS INSTITUTE

Tues., April 30.—Lecture Theatre, Institution of Electrical Engineers, Savoy Place, London, W.C.2, "Thermoplastics in the Submarine-Cable Industry," Sir John Dean, 6.30 p.m.

ROYAL AERONAUTICAL SOCIETY

Tues., April 30.—SECTION LECTURE : 4, Hamilton Place, London, W.1, "The Purpose and Problems of Research Aircraft," F. P. Youens, 7 p.m.

ROYAL INSTITUTION OF CHARTERED SURVEYORS

Mon., May 6.—ORDINARY GENERAL MEETING : Hoare Memorial Hall, Church House, Great Smith Street, Westminster, London, S.W.1, "The Rent Bill, 1957," R. E. Megarry, 5.45 p.m.

ROYAL STATISTICAL SOCIETY

Wed., May 1.—RESEARCH SECTION : London School of Hygiene and Tropical Medicine, Keppel Street, London, W.C.1, "Routine Analysis of Replicated Experiments on an Electronic Computer," F. Yates, M. J. R. Healy and S. Lipton, 5.15 p.m.

Fri., May 3.—INDUSTRIAL APPLICATIONS LONDON GROUP : E.L.M.A., Lighting Service Bureau, 2, Savoy Hill, London, W.C.2, "Some Simple Experiments," D. R. Cox, 6 p.m.

SOCIETY OF CHEMICAL INDUSTRY

Tues., May 7.—CORROSION GROUP : 14, Belgrave Square, London, S.W.1, Annual General Meeting and Chairman's Address, "A Pilgrim's Progress from Corrosion," T. H. Turner, 6.30 p.m.

Wed., May 8.—CORROSION GROUP EDUCATION PANEL : 14, Belgrave Square, London, S.W.1, Annual General Meeting, 11 a.m.

SOCIETY OF ENGINEERS

Mon., May 6.—Geological Society, Burlington House, Piccadilly, London, W.1, "Meteorology To-day," Sir Graham Sutton, 5.30 p.m.

SOCIETY OF INDUSTRIAL RADIOLOGY

To-day, April 26.—DISCUSSION GROUP : British Institute of Radiology, 32, Welbeck Street, London, W.1, "Non-Destructive Testing Methods and Techniques," 7 p.m.

SOCIETY OF INSTRUMENT TECHNOLOGY

Tues., April 30.—MAIN MEETING : Manson House, Portland Place, London, W.1, "The Preparation and Industrial Application of Diffraction Gratings," L. A. Sayle, 6.30 p.m.

SOCIETY FOR EXPERIMENTAL STRESS ANALYSIS

Wed. to Fri., May 1 *to* 3.—Hotel Statler, Boston, Massachusetts, U.S.A., 1957 Spring Meeting and Exhibit.

WOMEN'S ENGINEERING SOCIETY

Wed., May 8.—LONDON BRANCH : Hope House, 45, Great Peter Street, Westminster, London, S.W.1, "The Future Prospects for Nuclear Power," J. V. Dunworth, 7 p.m.

Advanced Engineering Courses

The Application of Work Study. UNIVERSITY OF BIRMINGHAM INSTITUTE FOR ENGINEERING PRODUCTION, "Southfield," 16, Norfolk Road, Edgbaston, Birmingham. Residential Executive Course, April 29 to May 10. Fee £50.

Operational Research. UNIVERSITY OF BIRMINGHAM INSTITUTE FOR ENGINEERING PRODUCTION, "Southfield," 16, Norfolk Road, Edgbaston, Birmingham. Senior Executive Residential Course. May 13 to May 24. Fee £50.

An Introduction to the Theory of Automatic Control. By C. R. Webb and B. B. Overy. MECHANICAL ENGINEERING DEPARTMENT, QUEEN MARY COLLEGE, UNIVERSITY OF LONDON, Mile End Road, London E.1. Ten-day course, September 16 to 27. Fee £6 6s.